



**FINAL REPORT  
OF THE  
SPACE SHUTTLE  
PAYLOAD PLANNING WORKING GROUPS**

**SPACE TECHNOLOGY**

**MAY 1973**

**NATIONAL AERONAUTICS & SPACE ADMINISTRATION  
GODDARD SPACE FLIGHT CENTER  
GREENBELT, MARYLAND 20771**

(NASA-TN-X-69457) THE SPACE SHUTTLE  
PAYLOAD PLANNING WORKING GROUPS. VOLUME  
10: SPACE TECHNOLOGY Final Report  
(NASA) <sup>88</sup>96 P HC \$7.00  
CSCL 22B

G3/31  
Unclas  
15963

N74-15527

## GLOSSARY

<u>Abbreviation</u>	<u>Word (Symbol)</u>
ACT	Active Cleaning Technique
AEC	Atomic Energy Commission
AMU or amu	atomic mass unit
ARC	Ames Research Center
ASPS	Active Scattering Particle Spectrometer
ATL	Advanced Technology Laboratory
CCRE	Controlled Contamination Release Experiment
CMG	Control Moment Gyro
CN	Communications and Navigation
CS	Components and Systems
EMI	Electromagnetic Interface
EN	Environmental Effects
EO	Earth Observation
EVA	Extra Vehicular Activity
GSFC	Goddard Space Flight Center
IRTCM	Integrated Real-Time Contamination Monitors
JPL	Jet Propulsion Laboratory (Pasadena)
kw	kilowatts
LaRC	Langley Research Center
LDEF	Long Duration Exposure Facility
LDV	Laser Doppler Velocimeter
LeRC	Lewis Research Center
LIDAR	Laser radar
LST	Large Space Telescope
mb	megabits
MB	Microbiology
MOS	Metal oxide semiconductor
MOS-FET	Metal oxide semiconductor - Field Effect Transistor
MS	Mass Spectrometer
MSC	Manned Spacecraft Center (Houston)
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NSF	National Science Foundation
OAST	Office of Aeronautics and Space Technology
PH	Physics and Chemistry
P.I.	Principal Investigator
QCMs	Quartz Crystal Microbalances
RCS	Reaction Control System
RNA-ase	Ribonuclease
R&QA	Research & Quality Assurance
RTG	Radioisotope Thermoelectric Generator
RTOP	Research & Technology Operating Plan
SPART	Space Research and Technology
SR&T	Supporting Research and Technology
TILM	Tunable Injection Laser Monochrometer
UV	Ultraviolet
VCM	Vacuum Condensable Material
VLCE	Visible Laser Communications Experiment
XUV	Extreme Ultraviolet

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Volume 10  
Space Technology

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NATIONAL AERONAUTICS & SPACE ADMINISTRATION  
GODDARD SPACE FLIGHT CENTER  
Greenbelt, Maryland 20771

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FOREWORD\*

In January 1972 the United States decided to develop a new space transportation system, based on a reusable space shuttle, to replace the present expendable system.

By January 1973 planning had progressed to the point that through the European Space Research Organization (ESRO) several European nations decided to develop a Space Laboratory consisting of a manned laboratory and a pallet for remotely operated experiments to be used with the shuttle transportation system when it becomes operational in 1980.

In order to better understand the requirements which the space transportation must meet in the 80's and beyond; to provide guidance for the design and development of the shuttle and the spacelab; and most importantly, to plan a space science and applications program for the 80's to exploit the potential of the shuttle and the spacelab, the United States and Europe have actively begun to plan their space programs for the period 1978-1985, the period of transition from the expendable system to the reusable system. This includes planning for all possible modes of shuttle utilization including launching automated spacecraft, servicing spacecraft, and serving as a base for observations. The latter is referred to as the sortie mode. The first step in sortie mode planning was the Space Shuttle Sortie Workshop for NASA scientists and technologists held at the Goddard Space Flight Center during the week of July 31 to August 4, 1972. For the purposes of that workshop, shuttle sortie missions were defined as including those shuttle missions which employ observations or operations (1) from the shuttle itself, (2) with subsatellites of the shuttle, or (3) with shuttle deployed automated spacecraft having unattended lifetimes of less than about half a year.

In general the workshop was directed towards the education of selected scientific and technical personnel within NASA on the basic capabilities of the shuttle sortie mode and the further definition of how the sortie mode of operation could benefit particular disciplines. The specific workshop objectives included:

- Informing potential NASA users of the present sortie mode characteristics and capabilities
- Informing shuttle developers of user desires and requirements
- An initial assessment of the potential role of the sortie mode in each of the several NASA discipline programs
- The identification of specific sortie missions with their characteristics and requirements

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\*Reprinted from the volume entitled "Executive Summaries".

- The identification of the policies and procedures which must be changed or instituted to fully exploit the potential of the sortie mode
- Determining the next series of steps required to plan and implement sortie mode missions.

To accomplish these objectives 15 discipline working groups were established. The individual groups covered essentially all the space sciences, applications, technologies, and life sciences. In order to encourage dialogue between the users and the developers attendance was limited to about 200 individuals. The proceedings were, however, promptly published and widely distributed. From these proceedings it is apparent that the workshop met its specific objectives. It also generated a spirit of cooperation and enthusiasm among the participants.

The next step was to broaden the membership of the working groups to include non-NASA users and to consider all modes of use of the shuttle. To implement both objectives the working group memberships were expanded in the fall of 1972. At this time some of the working groups were combined where there was appreciable overlap. This resulted in the establishment of the 10 discipline working groups given in Attachment A. In addition European scientists and official representatives of ESRO were added to the working groups. The specific objectives of these working groups were to:

- Review the findings of the GSFC workshop with the working groups
- Identify as far as possible the missions (by mode) that will be required to meet the discipline objectives for the period 1978 to 1985
- Identify any new requirements or any modifications to the requirements in the GSFC report for the shuttle and sortie systems
- Identify the systems and subsystems that must be developed to meet the discipline objectives and indicate their priority and/or the sequence in which they should be developed
- Identify any new supporting research and technology activity which needs to be initiated
- Identify any changes in existing procedures or any new policies or procedures which are required in order to exploit the full potential of the shuttle for science, exploration and applications, and provide the easiest and widest possible involvement of competent scientists in space science
- Prepare cost estimates, development schedules and priority ranking for initial two or three missions

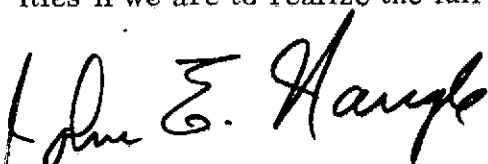
In order to keep this planning activity in phase with the shuttle system planning the initial reports from these groups were scheduled to be made available by the spring of 1973. It was also felt necessary that the individual working group activities be coordinated both between the groups and with the shuttle system planning. As a result, the steering group given in Attachment B was established.

Early in 1973, NASA and the National Academy of Sciences jointly decided that it would be appropriate for a special summer study to review the plans for shuttle utilization in the science disciplines. This summer study has now been scheduled for July 1973. It is anticipated that the results of the working group activities to date will form a significant input into this study.

In the following sections of the summary document are the executive summaries of each of the working group reports. While these give a general picture of the shuttle utilization plan, the specific plan in each discipline area can best be obtained from the full report of that working group. Each working group report has been printed as a separate volume in this publication so that individuals can select those in which they are particularly interested.

From these working group reports it is apparent that an appreciable effort has been made to exploit the full capability of the shuttle. It is, however, also apparent that much work remains to be done. To accomplish this important work, the discipline working groups will continue.

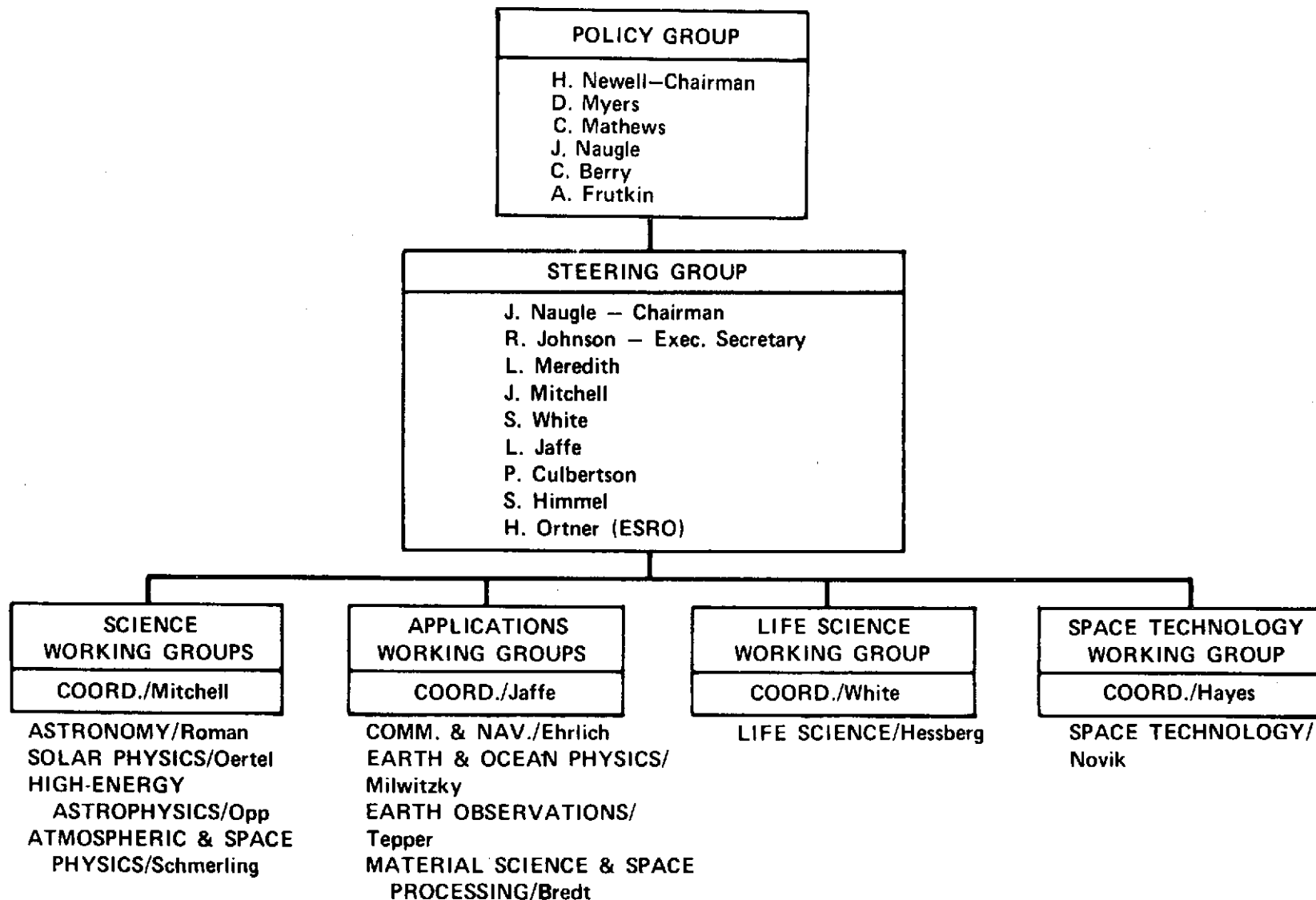
Finally it is evident from these reports that many individuals and groups have devoted appreciable effort to this important planning activity. I would like to express my appreciation for this effort and stress the importance of such activities if we are to realize the full potential of space systems in the 1980s.

  
John E. Naugle, Chairman  
NASA Shuttle Payload Planning  
Steering Group

## LIST OF WORKING GROUPS

	<u>GROUP NAME</u>	<u>CHAIRMAN</u>	<u>CO-CHAIRMAN</u>
1.	ASTRONOMY	Dr. N. Roman (HQ)	Dr. D. S. Leckrone (GSFC)
2.	ATMOSPHERIC & SPACE PHYSICS	Dr. E. Schmerling (HQ)	Mr. W. Roberts (MSFC)
3.	HIGH ENERGY ASTROPHYSICS	Dr. A. Opp (HQ)	Dr. F. McDonald (GSFC)
4.	LIFE SCIENCES	Dr. R. Hessberg (HQ)	Dr. D. Winter (ARC)
5.	SOLAR PHYSICS	Dr. G. Oertel (HQ)	Mr. K. Frost (GSFC)
6.	COMMUNICATIONS & NAVIGATION	Mr. E. Ehrlich (HQ)	Mr. C. Quantock (MSFC)
7.	EARTH OBSERVATIONS	Dr. M. Tepper (HQ)	Dr. W. O. Davis (DoC/NOAA)
8.	EARTH AND OCEAN PHYSICS	Mr. B. Milwitzky (HQ)	Dr. F. Vonbun (GSFC)
9.	MATERIALS PROCESSING AND SPACE MANUFACTURING	Dr. J. Bredt (HQ)	Dr. B. Montgomery (MSFC)
10.	SPACE TECHNOLOGY	Mr. D. Novik (HQ)	Mr. R. Hook (LaRC)

# NASA AD HOC ORGANIZATION FOR SHUTTLE PAYLOAD PLANNING





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## SPACE TECHNOLOGY WORKING GROUP

### EXECUTIVE SUMMARY

The Space Technology Shuttle Payload Program offers the potential of major multi-flight facilities that combine significant elements of low cost, broad participation and innovative management concepts. Elements of the program are summarized below:

Long Duration Exposure Facility—a 30 foot long by 14 foot diameter module that will be placed in orbit by the Shuttle, remain in orbit for about six months, retrieved by the Shuttle and returned to earth. The module will expose more than 1300 ft<sup>2</sup> of passive experiments to the synergistic effects of the space environment and requires no orientation, telemetry or power. As a facility, the module can be refurbished with hundreds of new experiments, in 4 ft x 6 ft panels, after each flight and flown again and again. This facility represents the epitome of low cost and will engender a maximum participation from the technical communities of the world. Anything that requires exposure to space - solar cells, thermal coatings, materials, sealants, microbes, seedlings, storage containers, etc., can be assembled into standard 4 ft x 6 ft panels, placed on the module for exposure and returned to the investigator for inspection on the ground after return from orbit. Because of its simplicity and low cost, the Long Duration Facility is currently planned as the payload for one of the first preoperational Shuttle orbital flights, to verify Shuttle deployment of a satellite, and on subsequent flights to verify Shuttle refurbishment and satellite retrieval techniques.

Advanced Technology Laboratory (ATL)—an experiment carrier that will be compatible with the Sortie Laboratory and will permit any NASA center to extend its laboratory programs into space. In this program LaRC will design and build a flight experiment carrier upon which it will mount, integrate and check a group of interdisciplinary experiments which are derived from and extend technology investigations that are part of the LaRC laboratory effort. Typical experiments include an investigation of the effects of the space environment on material fatigue life and fatigue crack propagation (sponsored by OAST) a determination of elemental abundances in meteoroids from uv meteor spectroscopy (sponsored by OSS) and measurements of atmospheric constituents and pollutants using a tunable laser (sponsored by OA). The experiment carrier, complete with checked-out experiments can then be shipped to the launch site for insertion into the Sortie Laboratory and then flown on the Shuttle. LaRC implementation of the concept will provide the design of the experiment carrier and a ground based Sortie Lab - ATL interface, demonstrate the feasibility and low cost potential of Center autonomy in the development and integration of interdisciplinary and inter-Program Office payloads, and will evolve the necessary innovations in management procedures. Definition of the Advanced Technology Laboratory must be in parallel with the progress on the Sortie Laboratory in order to ensure compatibility; one

immediate effect has been the preliminary selection of a complete end enclosure on the Sortie Lab rather than a 5 ft diameter opening, in order to permit insertion of the experiment carrier. A potential effect is possible inclusion of the experiment carrier as an element of the Sortie Lab development. In this case, LaRC would procure the already developed experiment carrier and proceed with the ATL from that point.

Physics and Chemistry Laboratory—a grouping of facilities that will provide the capability for investigations in fundamental physics and chemistry that cannot be accomplished on the ground. As differentiated from research on space (OSS) and research from space (OA), the weightlessness of orbital flight and the infinite vacuum sink of space will be exploited for doing research in space. Areas of research that have been tentatively identified include superfluidity, droplet dynamics, fluid flow and heat transfer, phase change phenomena and gas/molecular beam chemistry. The initial phase of the program is devoted to identification of specific investigations of significant interest to the scientific community. Subsequent phases of the program will define a sufficient number of these investigations to determine feasibility and to identify associated experiments, will group the investigations in accordance with mutual facility requirements (such as a gas chemistry facility) and will design and develop facilities for flight on an individual facility basis or as a dedicated laboratory, depending upon cost effectiveness.

The Physics and Chemistry program will provide a new area of space exploitation and will afford the opportunity to involve new segments of the scientific community on an international scale.

Contamination—a program in support of the Shuttle and Shuttle payloads, to provide real time measurement of the contamination environment and to develop a definitive model of the contamination problem. An Integrated Real Time Contamination Monitor (IRTCM) is being developed that will accompany virtually every Shuttle flight and that will provide immediate data on the extent of gaseous and particulate contaminants, the composition, the light scattering, the rate of deposition and the direction. The use of this instrumentation will also make it possible to implement an experiment in which known contaminants will be released so that the Shuttle contamination problem and theoretical models of contamination can be specifically verified.

Laser Information/Data Transmission—a major engineering experiment designed to verify laser information/data transmission technology in low earth orbit. In conjunction with a laser system on a synchronous satellite (similar to the OAST experiment that was being developed for flight on the cancelled ATS-G), the Shuttle laser experiment would verify the technology of a laser relay satellite system.



Following acquisition of sufficient experiment data the system will have operational potential for possible enhancement of Shuttle data transmission capabilities. Although this is the only major engineering system experiment now being defined, it is anticipated that additional ones such as laser power transmission and advanced Shuttle reentry configurations will be added to the program.

LONG DURATION EXPOSURE FACILITY  
ADVANCED TECHNOLOGY LABORATORY  
PHYSICS AND CHEMISTRY

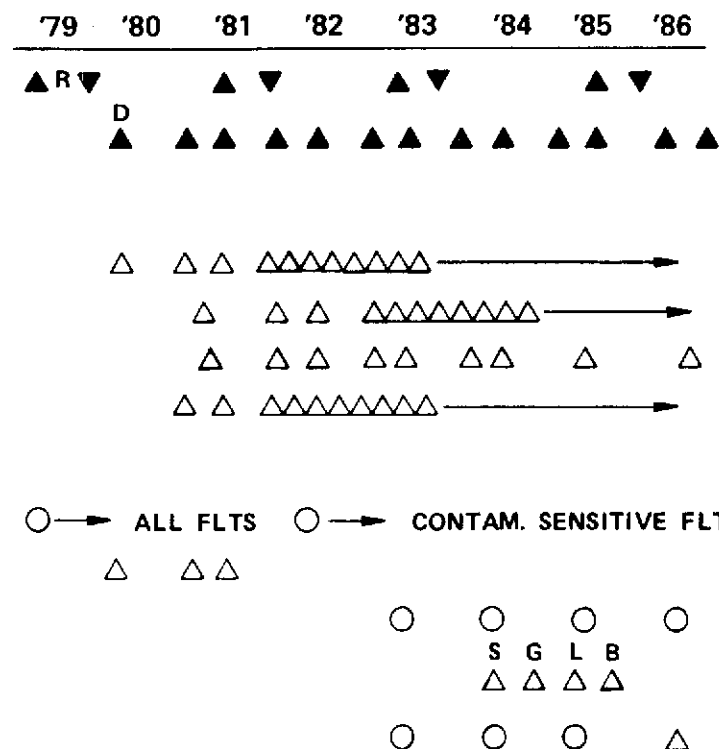
SUPERFLUID He AND DROP/PARTICLE POS.  
FLUID PHYSICS AND HEAT TRANSFER  
NEUTRAL BEAM FACILITY  
GAS CHEMISTRY AND MOLECULAR BEAM

CONTAMINATION

IRTCM (REAL TIME MONITOR)  
CONTROLLED CONTAMINATION RELEASE  
ADVANCED IRTCM

LASER INFO/DATA TRANSMISSION

NEW STARTS



- CARRY-ON OR SMALL EXPERIMENTS
- △ FACILITY MODULES
- ▲ FULL PAYLOAD OR MAJOR IMPACT
- ▼ PAYLOAD RETRIEVAL
- R REVISIT

- D - DEMONSTRATION
- S - TRANSMIT TO SYNCH. ORBIT
- G - TRANSMIT TO GROUND
- L - TRANSMIT TO LOW EARTH ORBIT
- B - BACK-UP OR OPERATIONAL CHECK

Figure 1. OAST Shuttle Payloads Mission Model

## REPORT OF THE SPACE TECHNOLOGY WORKING GROUP

### PANEL MEMBERS

<i>D. Novik, Hq., OAST, Chairman</i>	<i>J. Mugler, LRC</i>
<i>W. Hook, LRC, Co-Chairman</i>	<i>M. Saffren, JPL</i>
<i>F. Cepollina, GSFC</i>	<i>C. Tynan, LRC</i>
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<i>C. Wyman, MSFC</i>	<i>W. Wood, LRC</i>
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### INTRODUCTION

Future applications, space science, and exploration flight programs will require advanced systems and low-cost operational techniques. Although much of this technology can be developed with ground-based facilities, some test conditions (e.g., high-altitude, high-velocity, weightlessness, radiation, and earth orbital perspective) cannot be adequately or economically simulated on the ground. It is the objective of this working group report to define the usefulness of the Shuttle Sortie mode to the accomplishment of this work.

Advanced technology research and development efforts are required to provide the basic design data needed by the designers and planners of advanced space vehicles and missions. This multidiscipline technological data base can subsequently be used to design structures, subsystems, components, and instrumentation for the applications and scientific disciplines. The multidiscipline nature of advanced space technology was apparent from the wide variety of research activities embraced by the members of this working group. Each of these research areas has been treated as a separate discipline in this report.

Although advanced space technology covers a wide variety of disciplines, two classes of missions are identifiable:

- The advanced technology, laser communications and external contamination experiments would utilize the Sortie Laboratory.
- The development of the long duration exposure facility and entry technology research experiments would utilize the Shuttle to transport/deploy/retrieve objects or use the Shuttle itself as a test bed. A typical mission model (Figure 1) shows that the long duration exposure facility

LONG DURATION EXPOSURE FACILITY  
 ADVANCED TECHNOLOGY LABORATORY  
 PHYSICS AND CHEMISTRY

SUPERFLUID He AND DROP/PARTICLE POS.

FLUID PHYSICS AND HEAT TRANSFER

NEUTRAL BEAM FACILITY

GAS CHEMISTRY AND MOLECULAR BEAM

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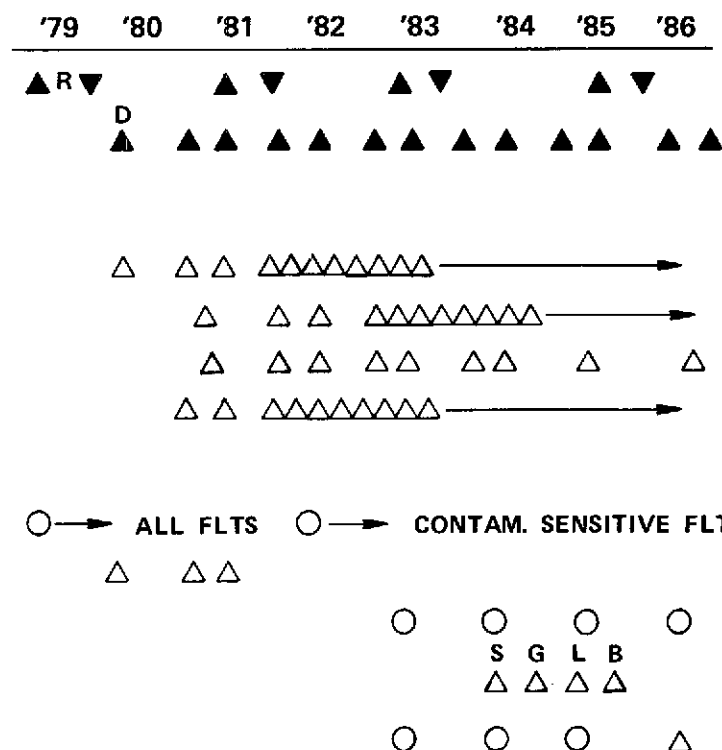


Figure 1. OAST Shuttle Payloads Mission Model

experiment could fly on early Shuttle missions since it is essentially a passive payload to be deployed from the Shuttle payload bay and left in orbit. External contamination experiments will fly on all missions for the first 3 years to define the Shuttle local external environment, all missions thereafter having contamination sensitive experimental equipment. The laser communications experiment can be integrated with the advanced technology experiments which will utilize two missions per year beginning in 1979. Entry technology experiments will be initiated in 1980.

## THE SORTIE LABORATORY

### DISCIPLINE AREA—ADVANCED TECHNOLOGY LABORATORY

An orbiting laboratory dedicated to the conduct of advanced research is a logical extension of present ground capabilities. The Langley Research Center (LaRC) is conducting an in-house study to define an Advanced Technology Laboratory (ATL) particularly suited to LaRC's technical expertise, including definition of its requirements, demonstration of technical feasibility, and development of detailed ground and flight equipment and facility requirements for a multidisciplinary advanced technology program.

### GOALS AND OBJECTIVES FOR THE 1980'S

An in-house NASA Study has defined a Shuttle-compatible Advanced Technology Laboratory particularly suited to Langley Research Center's technical expertise and research requirements. An ATL is simply a standard Sortie Laboratory equipped with unique experimental equipment and made ready for an assigned Shuttle Sortie flight. This approach provides a clear division of responsibility and allows NASA to utilize its existing organization to plan, organize, develop, direct, and control its contribution to Agency goals. In this way, a manageable, advancing, multidisciplinary-technology program can be maintained that will provide center researchers with routine access to space. As these advanced technology experiments are further refined, along with the more specifically discipline-oriented applications and scientific experiments, some of the multidisciplinary experiments proposed here could be integrated into singular-discipline oriented Sortie Laboratories. However, the results of this LaRC in-house study will provide an approach for accomplishing multidiscipline advanced technology experiments which can be evaluated by NASA Management.

### POTENTIAL CONTRIBUTIONS OF THE SORTIE MODE

In this in-house study, experiments and the associated prospective Principal Investigators (P.I.) were identified at LaRC alone. Due to the dynamic nature of research, these 30 experiments represent a snapshot in time of the space oriented portion of the research evolving in NASA. Because of the multidiscipline nature of these advanced technology experiments and organizational and function realignments with the Agency, some of these experiments may also be reported by other working groups. Some of them, in fact, may now more appropriately be accomplished by P.I.'s at other centers. This overlap of

experiments between working groups is considered to be unavoidable and even desirable at this time to ensure comprehensive results from the Shuttle Sortie workshops.

## EXPERIMENTS

The following is a list of advanced technology experiments:

### Communications and Navigation

- Microwave Interferometer Navigation and Tracking Aid — Objective: To determine the utility, limitations, and accuracy of a satellite interferometer technique at L-band for locating low-powered radio sources on the earth and on moving vehicles under a variety of weather conditions.
- Microwave Radiometer Measurements — Objective: To develop and test new microwave components and techniques in low-earth orbit; to make day/night measurements of ocean temperature and sea state using microwave radiometers under varying meteorological conditions; to measure RF radiation from galactic sources.
- Precision Laser Ranging and Altimetry — Objective: To determine the utility, limitations, and accuracy of a mode-locked laser-ranging system to measure range, line-of-sight angles, and range rate; to evaluate the utility of on-board laser-ranging to measure range to within  $\pm 3$  cm over ATL to ground distances; to isolate problems that may be associated with the use of laser ranging in the earth-space environment; to determine optimal engineering parameters under various modes of operation and operating conditions.
- Autonomous Navigation — Objective: To determine the utility, limitations, and accuracy of a number of navigation techniques for determining orbital position relative to earth ground track under identical environmental conditions; to measure sensor accuracy and overall system error to aid in testing analytical error models under a variety of environmental conditions; to flight test a holographic starfield and landmark tracker and a ground beacon tracker.
- Microwave Altimetry — Objective: To determine the utility, limitations, and accuracy of a microwave altimeter for all-weather use in accurately measuring relative earth surface height variations; to determine the accuracy of measuring scattering cross-section density for different

surface features and compositions falling within the altimeter target area; to investigate the simultaneous use of the altimeter as a passive radiometer operating at a different frequency band or between radar returns. (To measure relative change in emissivity of target areas.)

- Search and Rescue Aids — Objective: To determine, via in situ measurements, the utility, limitations, and accuracy of detecting, identifying, and positioning earth-located passive targets on vehicles in emergency situations using an orbiting side-looking radar system for detection and location.
- Multipath Measurements — Objective: To measure the statistical properties of signals simultaneously received over multiple propagation paths between Shuttle-type vehicles and relay satellites; to determine the utility of an analytical multipath model for predicting signal fading.
- Imaging Radar — Objective: To determine the utility, accuracy, and limitations of an imaging radar in low-earth orbit.
- RF Noise — Objective: To measure the electromagnetic interference (EMI) at orbital altitudes in the frequency spectrum of 400 MHz to 15 GHz.

#### Earth Observations

- Lidar Measurements of Cirrus Clouds and Lower Stratospheric Aerosols — Objective: To measure the spatial distribution of cirrus clouds and lower stratospheric aerosols. A satellite-borne laser radar (lidar) will be developed for these measurements.
- Tunable Lasers for High Resolution Studies of Atmospheric Constituents and Pollutants — Objective: To develop a flight-qualified tunable injection laser monochrometer (TILM) system for remote sensing of the earth's atmospheric constituents and pollutants and for in situ measurements of atmospheric constituents and pollutants near the spacecraft.
- Multispectral Scanner for Coastal Zone Oceanography — Objective: To obtain narrow-band spectral signatures of coastal zone features from a spacecraft as a function of spatial resolution and field of view.
- Shuttle Delivery of Atmospheric and Oceanographic Ground Truth Payloads — Objective: To obtain meteorological/oceanographic data from the mid-latitudes of the southern hemisphere, with initial payloads providing air pressure, wind speed, wind direction, air temperature and water circulation data through a satellite link.



## Physics and Chemistry

- Spacecraft Wake Dynamics — Objective: The primary objective is to determine the parameters governing the flow around ionospheric satellites or space stations. Of particular interest are the spatial extent and properties of the wake region of the spacecraft. The wake of a large body is created primarily by the body sweeping out ions from the ambient plasma and thereby causing large disturbances in the local ion and electron densities. In the interpretations of the measurements of geophysical properties made with satellite-borne instrumentation it is important to determine the effects of satellite-caused perturbations.
- Barium Plasma Cloud Release on Sunward Side of the Earth — Objective: To monitor the natural magnetospheric plasma convection patterns on the sunward side of the earth.
- Optical Properties of Aerosols — Objective: To obtain a detailed knowledge of the interrelationship between the size, shape, concentration, and composition of aerosols and their optical properties under various meteorological conditions.
- Mapping of Upper Atmospheric Neutral Gas Parameters — Objective: To measure on a global scale the neutral number density of each constituent of the upper atmosphere and the temperature of the upper atmosphere as a function of latitude, longitude, height, and time using molecular beam techniques.
- Spacecraft Radiation Environment — Objectives: The internal radiation environment of the ATL will be characterized in terms of radiation type, energy, intensity, and direction. This information will be processed in real-time to provide an accurate description of the radiation dose received by the crews. All data will be retained for detailed postflight analysis.
- Ultraviolet Meteor Spectroscopy from Near Earth Orbit — Objective: To obtain quantitative spectra of meteors in the wavelength region below 3100 Å (the atmospheric ozone cutoff).

## Microbiology

- Colony Growth in Zero Gravity — Objective: To investigate the pattern of growth of bacteria colonies in near zero gravity.

- Interpersonal Transfer of Micro-organisms in Zero Gravity — Objective: To investigate the interpersonal transfer of micro-organisms between crewmen in a condition of weightlessness.
- Electrical Field Opacity in Biological Cells — Objective: To define the electrical field opacity error involved in measuring cell volumes using ground-based electronic techniques.
- Electrical Characteristics of Cells — Objective: To measure the electrophoretic mobility, surface zeta-potential, and surface-charge density of selected mammalian cell lines over the life cycles of the cells under weightless conditions; to investigate electrophoretic methods which take advantage of a weightless environment to determine the electrical characteristics of cells.
- Special Properties of Biological Cells — Objective: Utilize weightlessness to perform a series of advanced studies to determine physical properties of mammalian cells.

#### Components and Systems Testing

- Carbon Deposition and Transport in Zero Gravity — Objective: To determine how carbon forms on a reduction or disproportionation catalyst in zero gravity and how the carbon can be periodically removed from the catalyst and transported by a continuous or intermittent recycle gas flow to a collection device.
- Steam Generator — Objective: To obtain steam generator performance data while the generator is operating at reduced gravity levels in earth orbit.

#### Environmental Effects

- Sampling of Airborne Particles and Micro-organisms in Space Cabin Environment — Objective: Postflight analysis of experimental data obtained during a manned earth orbital mission is expected to provide: the types of micro-organisms present in the cabin air environment; quantification of these micro-organisms types; the rate of change of these micro-organism types with respect to operations of, and in, the spacecraft; the types, quantity and rates of change of non-viable particles; the origin of the non-viable particles (in some cases); classification of both viable and non-viable particles as to size.

- Orbital Fatigue Experiment — Objective: To obtain in situ data on the effects of the space environment on: material fatigue life characteristics; fatigue crack propagation.
- Environmental Effects on Nonmetallic Materials — Objective: To collect in situ data on the effects of the near-earth space environment on elastomers, coatings and polymeric films.
- Fluids in Zero Gravity — Objective: To validate a set of analytical models which attempt to describe and predict the behavior of fluids in a reduced gravity environment.

## REQUIRED SORTIE MISSIONS

The individual experiments listed above have been defined in sufficient depth to permit their grouping into selected payloads. Fully recognizing the capabilities of the Shuttle and Sortie Laboratory (through close coordination with MSC and MSFC personnel), it has been determined that the 30 Langley experiments can be grouped into three 7-day Shuttle Sortie mission payloads and can be scheduled to: (1) fully utilize the Sortie/ATL facility, (2) fully utilize a two-man experiment crew and (3) perform nearly every experiment one or more times. The "Requirements on the Shuttle" for these three payloads are listed in Appendix A. Just as advanced technology research and development efforts are multidiscipline in nature, these three mission payloads are necessarily multidiscipline in composition in order to maximize utilization of the capabilities provided by the Sortie Laboratory's pressurized module and unpressurized pallet. Although some experiments can be included as repeats on all three of the payloads, some can only be accommodated one time; for example, the communications and navigation experiments may be performed one time, all other experiments could be performed an average of 2.1 times. A major problem is that the number of scheduled view opportunities for ground targets is less than desired because of conflicts between experiment tasks and crew sleep requirements as well as conflicts among experiments. This problem can be alleviated by extending the 7-day mission duration, increasing crew complement, and/or using more 7-day flights.

## PROPOSED TOTAL FLIGHT SCHEDULE

It appears that LRC researchers will provide sufficient experimental payloads to utilize two 7-day Shuttle Sortie missions each year commencing in 1980. This forecast is based upon the following:

- The presently identified P.I.'s want to fly their experiments many times for statistical purposes and to modify experimental equipment and/or procedures.

- The number of involved researchers and experiments will noticeably increase when it becomes a reality that researchers truly have routine access to space.

## DISCIPLINE AREA—LASER COMMUNICATIONS

### LASER COMMUNICATIONS

The Marshall Space Flight Center is evaluating laser communications for consideration as part of a world-wide communications system. Shuttle Sortie missions can aid in the development of those links involving low earth orbit systems by utilizing existing ground stations. The objectives of these experiments will be to generate scientific and engineering data and to develop parameters from these data in order to evaluate designs for future operational system consideration. This research will provide the necessary technology evaluation for use in developing a worldwide, extremely high bandwidth, communications network probably consisting of a hybrid microwave/laser system with deep space capability.

### GOALS AND OBJECTIVES FOR THE 1980'S

The development of laser/optical communications for a variety of eventual space uses has been identified as a specific program objective of NASA. Laser communications will eventually be used for deep space communications, for synchronous data relay satellites, and for low-earth-orbit satellites. Low-earth-orbit satellites may communicate continuously with a system of synchronous data relay satellites which then relay the information to ground, or they may dump information at very high rates directly to ground stations on each pass overhead.

Communication satellites for both civilian and military purposes are already a reality. A huge expansion of communications capacity via satellites for both military and civilian purposes is expected during the next 20 years. Data-relay-satellite and low-earth-orbit systems to synchronous systems will eventually use lasers almost exclusively. Depending on the applications and requirements, microwave or hybrid microwave/laser systems may be used from synchronous orbit to ground and low-earth-orbit to ground. Developments now taking place will help define the efficacy of direct communications between spacecraft and ground via laser systems and will help to define the circumstances directing use of lasers. These experiments will also help to define whether deep space systems should communicate directly to ground or through a data-relay-satellite system.

In summary, the goals and objectives of laser communications are to aid in the huge expansion of world wide communications capability which is expected to take place during the next 20 years, including communications for deep space purposes.

## POTENTIAL CONTRIBUTIONS OF THE SORTIE MODE

The Sortie mode can contribute to the development of three modes of laser communications:

- Communications between low-earth-orbit systems and synchronous altitude systems.
- Communications between two or more low-earth-orbit systems.
- Direct communications between low-earth-orbit systems and ground.

In particular, the Sortie mode, by flying experimental low-earth-orbit laser communication systems in the shuttle, can contribute to these developments by:

- Communicating with synchronous laser communication systems such as the visible laser communication experiment (VLCE).
- Communicating with existing laser communications ground stations.
- Communicating with low-earth-orbit satellites, possibly deployed by the shuttle itself. The purpose of the flights will be to demonstrate the laser communications systems and to make scientific and engineering evaluations of the link parameters and system characteristics.

Eventual operational systems will require bandwidths from the hundreds of megabits to several gigabits. Early experimental systems such as might be flown on the Shuttle Sortie missions can demonstrate most of the capabilities and evaluate most of the link parameters and system characteristics with lower bandwidths, such as thirty megabits to two hundred megabits.

## REQUIRED SORTIE MISSIONS

- Low-earth-orbit to synchronous-satellite-laser communication experiment.

- Low-earth-orbit to ground laser communication experiment.
- Low-earth-orbit to low-earth-orbit-laser communication experiment.

## SORTIE MISSIONS

(See Appendix B for outline.)

## PROPOSED TOTAL FLIGHT SCHEDULE

The state-of-the-art of laser communications is such that a series of experimental systems could be flown on the earliest Shuttle Sortie missions. In particular, the VLCE ground station will exist and be available for updating in time for the earliest flights to conduct low earth orbit to ground station experiments. To conduct the low-earth-orbit to synchronous orbit experiments, a VLCE type satellite will need to be launched. A similar package could be flown to orbit by the shuttle and be released in low earth orbit to demonstrate the low-earth-orbit to low-earth-orbit link by communicating with the shuttle.

For purposes of this document a minimum of three flights is proposed, one each year for the first three years of Shuttle Sortie mode availability, with a separate synchronous payload launched in 1979 to communicate with a Shuttle Sortie or Sortie payload also launched in 1979. The proposed flights are as follows:

- 1979 — Synchronous satellite launch plus a Shuttle Sortie mission to demonstrate and evaluate the low-earth-orbit to synchronous orbit laser communications
- 1980 — Shuttle Sortie mission to demonstrate and evaluate low-earth-orbit to ground laser communications
- 1981 — Low-earth-orbit satellite launched via shuttle to communicate with second package on shuttle.

By the end of this series the capabilities and requirements of laser communications will be defined to the point that operational systems may be developed. It is entirely possible that at this point laser communications can be used to expand and update the communications capability of the shuttle itself.

## DISCIPLINE AREA—EXTERNAL CONTAMINATION

### EXTERNAL CONTAMINATION

In order to ensure an acceptable environment for Shuttle Sortie experiments, the Marshall Space Flight Center (MSFC) is studying methods to eliminate or alleviate external contamination problems. These methods include:

- minimizing the initial release of contaminants by basic design practices
- reducing contamination inherent in manufacture, test, deployment and operation of payloads
- controlling operational events which contribute contaminants
- characterizing the shuttle-induced environment and determining the effects on optical and other critical spacecraft and experimental surfaces
- providing techniques for removing contaminant deposition in situ.

### GOALS AND OBJECTIVES FOR THE 1980'S

The goal of this discipline area is to ensure a contamination-free environment for the entire shuttle cluster. The objectives listed below are designed to achieve this single goal. This discipline area does not include biological, manufacturing, or interior-cabin atmosphere except in the respect that they could cause a degradation in performance of optical systems. The overall objectives in the area of external contamination are:

- Minimize, by basic design of the Shuttle Sortie Lab and shuttle payloads, the amount and types of contaminants which may be released to the environment of the shuttle
- Manufacture, test, launch and deploy the payloads and the other modules with the view toward reducing contamination
- Control on-board operational events of the various modules to preclude or reduce the potential for contamination
- Monitor the environment of the shuttle cargo bay in the vicinity of contamination-sensitive systems or surfaces to provide data needed to

make operational decisions to close aperture doors, for example, or to make corrections in observational data

- Provide techniques and devices to further define the dynamic characteristics of the induced environment of the shuttle
- Provide techniques and devices which will remove contaminant material from the critical surfaces of external systems in situ.

## POTENTIAL CONTRIBUTIONS OF THE SORTIE MODE

It is assumed that various optical experiments, diverse monitors using optics, and critical thermal control surfaces are being proposed by other discipline areas for utilization of the Sortie mode. Many of these systems can become seriously degraded by such things as RCS engine firings, waste dumps, experiment venting, and the outgassing of the nonmetallic materials used in any of the modules. Realistically, there will be degrading contamination present in the vicinity of the optical systems. Therefore, monitoring and abatement devices must be provided for the Shuttle Sortie mode optical experiments and other sensitive experiments or systems.

## REQUIRED SORTIE MISSIONS

- Contamination-related equipment is required on each Sortie mission which contains experiments or any other system whose performance could become degraded if exposed to an induced atmosphere.
- This equipment, or modified versions of it, should be included on those Sortie missions which are known to produce significant amounts of contaminants in the form of particulates or vacuum condensable material (VCM).

## SORTIE MISSIONS

(See Appendix C for outline.)

- All optical astronomy payload missions
- All Manufacturing-in-Space missions
- All missions containing critical optical, thermal, or other surfaces.



## PROPOSED TOTAL FLIGHT SCHEDULE

- ◉ 1979 — All mission flights
- ◉ 1980 — All mission flights
- ◉ 1981 — All mission flights
- ◉ 1982-1990 — All optical payload missions or missions whose payloads may be sensitive to the effects of contamination.

LONG DURATION EXPOSURE FACILITY  
(A LOW COST, HIGH RETURN MODE OF OPERATION  
FOR SPACE SHUTTLE)

DISCUSSION

The Space Shuttle, when operational, will permit many new approaches to space operations. The reduced costs of shuttle launch and payload return capability, coupled with the relatively large payload weight and volume accommodations of the shuttle, are in fact already impacting the conceptional designs for future spacecraft. The new approaches for Sortie type space operations, via shuttle, using Sortie Laboratories are already rapidly being recognized and developed. The Long Duration Exposure Facility has been identified as still another shuttle related approach to future space operations.

The LDEF is conceptionally a low cost, simple, free flying, gravity gradient stabilized structure on which many different totally self contained experiment packages can be mounted for transportation to and from space via shuttle. This unmanned, unattended, space facility is intended to provide an easy access, low cost means for carrying out a wide variety of experiments for large numbers of researchers, many of whom have had no previous space experience. Types of experiments that are particularly suited for LDEF are the following:

- Experiments that require stay times in space beyond the capability of the Shuttle and Sortie Laboratory.
- Experiments that require extended periods of very near zero "g", which is difficult to achieve with a manned vehicle.
- Experiments that either require a contamination free environment or produce a contaminant environment that is incompatible with the Shuttle and Sortie Laboratory.
- Experiments that are too hazardous to be performed near the shuttle.

LDEF is currently conceived as a cylindrical structure made up of ring frames and longerons, 30 ft. in length and 14 ft. in diameter. The structure provides for the mounting of 60 trays on the circumferential surface. Each tray, which is 4 x 6 feet and may be several feet deep, will hold a completely self-contained experiment or, if needed, several adjacent trays may contain the individual elements of a single experiment. Shelves in the LDEF bay have also been designed for the mounting of experiments. The LDEF has been designed for

refurbishment after a mission, re-equipment with a new set of experiment trays, and reuse at a later launch opportunity.

Experiments which have been identified and which can be performed on these missions include the areas of meteoroid technology and science, microbiology and macrobiology, as well as materials, components and systems technology and science. The first exposure facility will stress meteoroid technology and science and will carry samples from the latter two areas. Later exposure facilities will be concerned principally with the latter two areas. The pages which follow contain particular experiments from these areas along with their justification.

#### DISCIPLINE AREA—PARTICULATE MATTER IN SPACE (METEORIODS, COSMIC DUST AND MAN-MADE DEBRIS)

##### METEOROID EXPERIMENTS

The use of a large-area free-flying module makes possible a clear definition of the meteoroid environment. Not only can the meteoroid hazard to large, long-duration spacecraft be defined but, also, interesting new fields connected with the hazard to spacecraft from man-made debris and the impact of extra-terrestrial material on the upper atmosphere particulate airburden can be studied. Recovery of the module enables many scientific experiments, which heretofore have been impossible, to be conducted on meteoroids. In fact, many of the experiments listed in this section are such that they are both of a technological and scientific nature.

##### GOALS AND OBJECTIVES FOR THE 1980'S

The broad goal will be to perform both scientific and technological investigations of particulate matter in space. Specifically, the objective of these investigations will be to better define the population/mass relationship — the composition and structure, the origin, and the probability for an effects of collisions between these particles and spacecraft.

A thorough understanding of meteoroids and cosmic dust in space is essential before man can develop a sound understanding of the origin and evolution of our solar system. Therefore, these investigations of particulate matter in space support a basic scientific goal of NASA.

An understanding of the particulate environment of space and the probability for and the effects of collisions between these particles and spacecraft is necessary to design low-cost effective meteoroid protection systems for the large long-life spacecraft such as research modules, tugs, and space stations planned for the late 1980's and the 1990's.

Investigations of man-made debris are a critical part of these particulate matter studies. The time is rapidly approaching, if it has not already arrived, when man-made debris in space will be more critical to future space operations than the natural meteoroids of celestial origin. For example, recent spacecraft explosions in near-earth orbit, some of which were accidental and some of which were probably planned, (particularly several Russian spacecraft explosions) resulted in increases of many orders of magnitude in the number of large particles having sufficient mass to result in critical-impact damage to near-earth spacecraft. In many cases these man-made debris particles will remain in space posing a threat to spacecraft for many years. Debris also accumulates in space from routine operations such as spacecraft dumps and shroud and adapter separations.

A second new and interesting area which is of particular concern to environmentalists is the impact of airborne particulates on the weather. The portion of the particulate airburden due to extra-terrestrial material forms a natural benchmark against which man's contribution may be measured. The importance of volcanic activity is even now recognized as influencing the particulate airburden; large area meteoroid counting experiments can be expected to prove or disprove the importance of the extra-terrestrial activity.

#### **SORTIE MODE CONTRIBUTIONS TO PARTICULATE MATTER STUDIES — EXPOSURE MODULE EXPERIMENTS**

Sortie missions to deliver into space and later Sortie missions, to retrieve from space, large, simple, very inexpensive and, in some cases, near-passive Exposure Modules will reveal more about the near-earth meteoroid environment in the mass range between  $10^{-15}$  and  $10^{-5}$  grams than the combined knowledge obtained from all previous meteoroid flight experiments. The module can be relatively simple, as shown in Figure 2. The module will perform a number of experiments to obtain needed data on the meteoroid environment in space and the effects of the meteoroid environment on spacecraft.

#### **Environment Definition Experiments**

The present best estimate of the near-earth meteoroid environment is the model presented in the NASA space vehicle design criteria document NASA SP-80B.

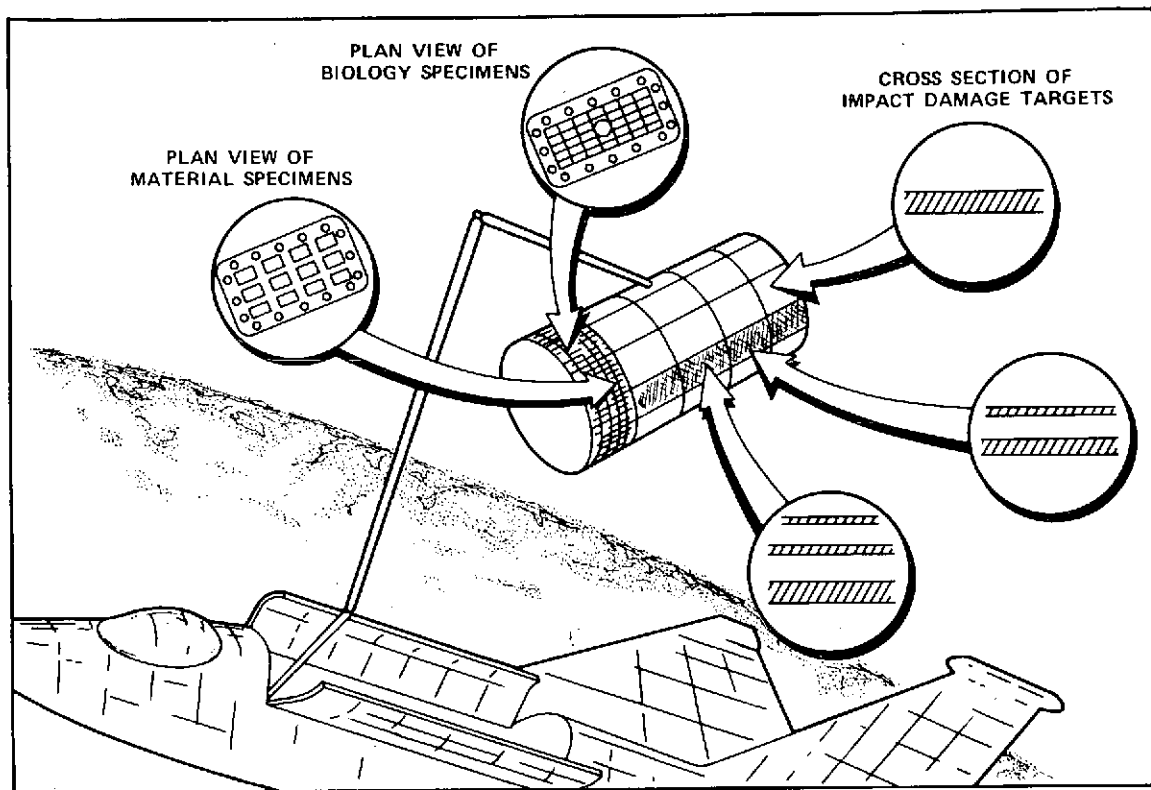


Figure 2. Long Duration Exposure Facility

The curve of the meteoroid impact flux as a function of meteoroid mass which is predicted by this model is shown in Figure 3. This curve is based essentially on three sets of experimental data: the Explorer pressure cell penetration data, the Pegasus capacitor discharge penetration data, and photographic meteor data. None of these data contain direct measurements of meteoroid mass as a function of impact flux.

The Explorer data consist of measurements of meteoroid penetration rates in 1- and 2-mil thick steel plates. A penetration here is defined as an impact which rendered the plate incapable of maintaining a pressure differential. The Pegasus data consist of measurements of meteoroid penetration rates in 8- and 16-mil thick aluminum plates. However, in the Pegasus data, a penetration is defined as an impact which caused a charged capacitor, bonded to the rear of the plate, to discharge below the threshold level which was required for detection.

The meteor data represent a third and even more different set of measurements taken from the photographic plates of observed meteors — namely measurements

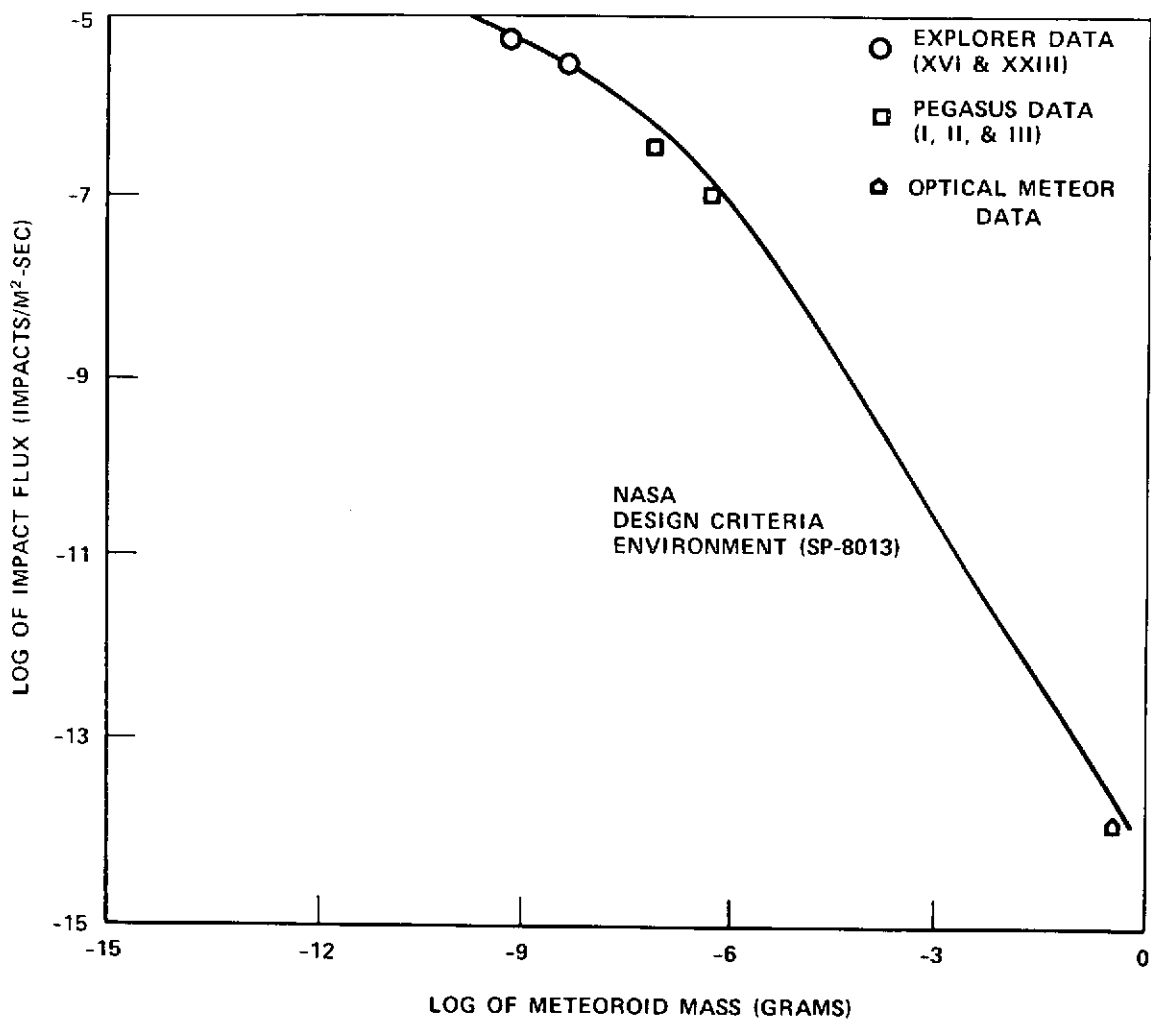


Figure 3. Current Best Estimate of Near Earth Meteoroid Environment

of luminosity, velocity, and counts of meteors in the earth's atmosphere. There is a great deal of uncertainty in the estimated mass or penetrating capability of the meteoroid responsible for any observed meteor.

The Explorer, Pegasus, and photographic meteor data also represent measurements made in widely separated meteoroid mass ranges. Because different detectors were used, different quantities were measured, and since the measurements were made in widely separated ranges it is difficult to relate the Explorer, Pegasus, and photographic meteor data. It is even more difficult to establish the true meteoroid mass flux environment with the data. No meaningful uncertainty limits can presently be placed on the estimated meteoroid mass flux environment.

The launch and later recovery of a simple exposure module will allow identical measurements to be made over a meteoroid mass range of approximately 10 orders of magnitude as is indicated on Figure 4. The measurements can start with meteoroids having masses approximately 5 orders of magnitude below those detected by the Explorer satellites and extend to meteoroids having masses several orders of magnitude greater than those detected by the Pegasus satellites. Such a set of consistent measurements will allow greatly improved environment models to be constructed.

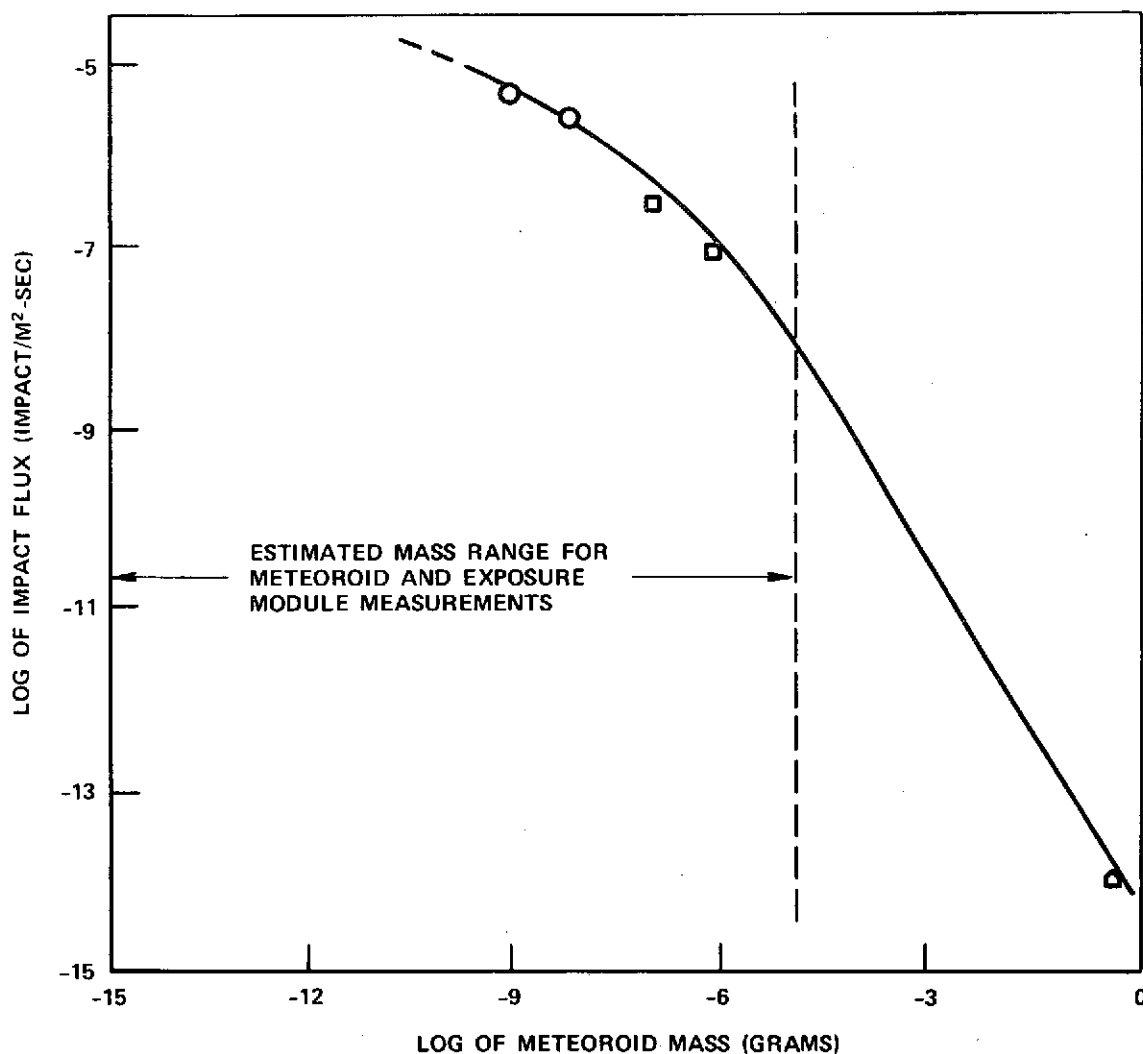


Figure 4. Estimated Mass Range for Meteoroid and Exposure Module Measurements

In addition to permitting consistent measurements to be made over a large mass range, the recoverable feature of the meteoroid and exposure module will permit more definitive measurements than have been possible on previous meteoroid satellites. For example, the exact penetration capability of each impacting meteoroid can be measured with the module. The Explorer and Pegasus satellites could only measure the total number of impacts which resulted in penetration depths greater than some threshold level. More importantly, the module will allow detailed laboratory examinations of each meteoroid crater or penetration. Such laboratory examinations can reveal important clues to better estimate the mass of the impacted meteoroid, its density, structure, composition, and other characteristics and effects.

#### Meteoroid Detector Experiments

The complete spectrum of meteoroid impacts which are expected in space cannot be simulated in the laboratory for two reasons. First, insufficient knowledge exists to physically describe meteoroids. Second, the available laboratory particle accelerators are limited to velocities which are considerably less than the average meteoroid velocity in space. Therefore, the response of meteoroid detectors to the complete spectrum of expected meteoroid impacts cannot be studied in the laboratory. This fact introduces many uncertainties into the analysis of the data from these detectors. Some of these uncertainties can be eliminated by exposing the instrument in space and later returning it to the laboratory for study. In this manner, the instrument response signals recorded during the exposure in space can be compared later with the craters or penetration observed in postflight laboratory examinations of the instrument.

#### Meteoroid Damage Experiments

Spacecraft designers must not only know the meteoroid environment, they must also know the damage the environment will inflict on spacecraft. The exposure module will permit experiments to directly determine the types of damage that can result from meteoroid impacts. For example, the examination of witness plates, which will be located behind thin skins on the module while in space, can establish the pattern and damage capability of the spray that is ejected when spacecraft skins are penetrated or spalled. Examination of penetrated multi-sheet panels can establish if the damage is confined to a small region around the impact, or, if blast loading produces large cracks which propagate away from the impacted area thus substantially degrading the integrity of the panel. This type of information is critical to establish a tolerable level for meteoroid damage.



## Sortie Laboratory Experiments

Active experiments to observe and study meteors from space can be performed with cameras and spectrosopes mounted on the Sortie Laboratory. Such experiments can contribute to a better understanding of larger mass meteoroids (greater than  $10^{-5}$  grams). Specifically, quantitative spectroscopy of meteor radiation provides a powerful method for determining elemental abundances in meteoroids. Current ground-based techniques provide meteor spectra in the 3100 Å to 9000 Å wavelength region. Observations of meteors from above the atmospheric ozone region would extend the wavelength region below the 3100 Å ozone cutoff to near 2000 Å. This region, from 2000 Å to 3100 Å, is extremely important in that a number of elements suspected to be present in meteoroids radiate strongly there. Some of the spectral lines that are important in meteor spectroscopy are shown in Figure 5.

Quantitative spectroscopy is now available and being analyzed for meteor radiation in the wavelength region 3100 Å to 9000 Å. These data are being used to measure the elemental abundances and their distribution in different kinds of meteoroids.

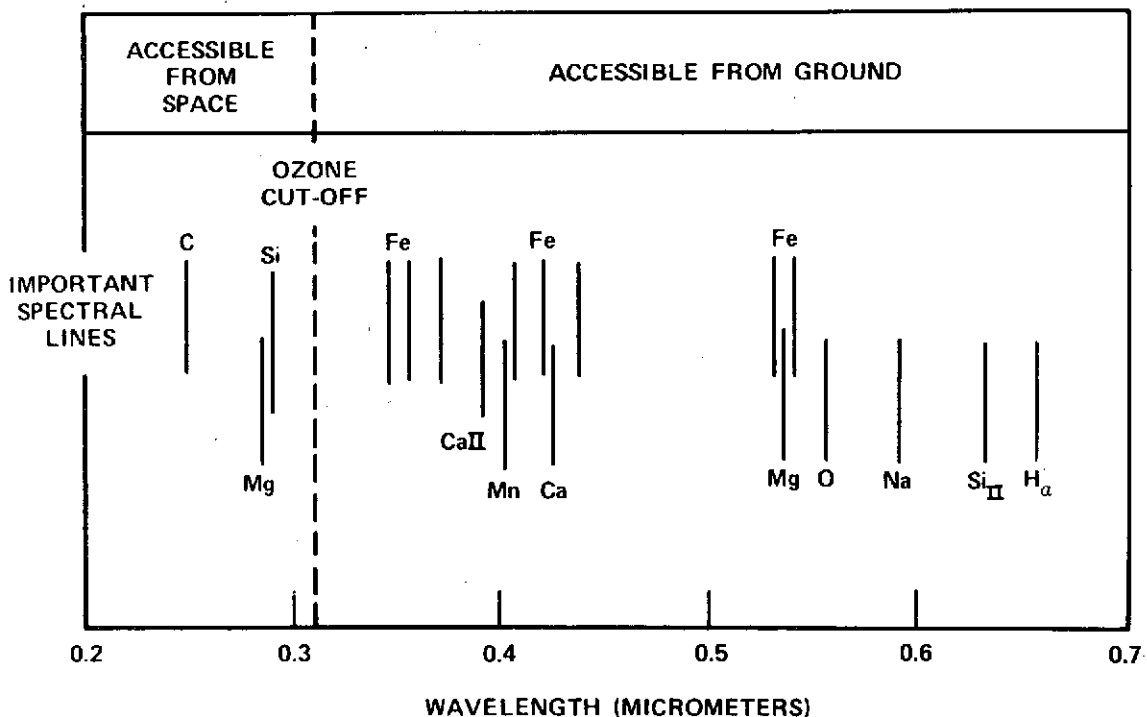


Figure 5. Some Spectral Lines That Are Important In Meteor Spectroscopy

Carbon is of major interest in the origin and evolution of the solar system, and is suspected to be present in most cometary meteoroids and hence in most meteoroids. If carbon is not present, it indicates that the meteoroid is not of cometary origin. Absence of carbon also indicates a much stronger material. Carbon cannot be detected in the presently accessible wavelength region, but has a strong line at  $2478\text{\AA}$ . Silicon is of major interest in meteoroids because, combined with oxygen, it is believed to make up most of the mass of most meteoroids. Silicon is almost never seen in present meteor spectra because the weak  $3905\text{\AA}$  line is masked by stronger iron lines. A strong silicon line exists at  $2881\text{\AA}$ .

Magnesium is the most abundant metal found in most stony meteorites. Although magnesium has two strong triplets in the presently accessible wavelength region (multiplet 3 at  $3835\text{\AA}$  and multiplet 2 at  $5180\text{\AA}$ ), both of these multiplets are above metastable states of magnesium, which introduces a large uncertainty in magnesium abundance determinations. Use of the strong, ground-state magnesium line at  $2852\text{\AA}$  would circumvent this problem. Measurements of the  $2802\text{\AA}$  ionized magnesium line would aid significantly in the study of meteor ionization. Two strong iron lines at  $2533\text{\AA}$  and  $2719\text{\AA}$  would serve as convenient calibration lines.

Measurements of these lines must be made from above the earth's ozone layer (50-60 kilometers altitude). It is now within the state-of-the-art to make an automatic meteor-sensing-and-triggering, middle-ultraviolet, widefield spectrograph of high-spectral sensitivity to obtain the required spectra. Such spectrographs, mounted on the Sortie lab can obtain the desired data while viewing the dark side of the earth's atmosphere.

Most meteoroids are believed to be extremely fragile. They are observed to break-up when entering the earth's atmosphere at dynamic pressures of only a small fraction of an atmosphere. Such particles can probably never be trapped or captured without damage. High speed photographic systems can be operated from the Sortie lab to obtain detailed pictures of meteoroids. These will be of tremendous value in determining the structure of the meteoroid in turn will provide many clues as to it's origin and evolution.

Man-made debris can be routinely monitored using optical systems on Sortie missions. The optical systems to be used will provide data on the orbit and size of the debris. Such systems will also provide data on orbits of natural meteoroids.

## REQUIRED SORTIE MISSIONS

Sortie missions are required for:

- The long Duration Exposure Facility
- Ultraviolet Meteor Spectroscopy from Near Earth Orbit (1 experiment possibly on a Sortie lab module)
- Meteoroid Photography (1 experiment possibly on a Sortie lab module)
- Man-Made Debris Monitoring (1 experiment possibly on a Sortie lab module)

## SORTIE MISSIONS

- Long Duration Exposure Facility  
(See Appendices D and E for outline)

## PROPOSED FLIGHT SCHEDULE

- 1979 — Meteoroid and Exposure Module
- 1981 — Exposure Module
- 1984 — Exposure Module

## DISCIPLINE AREA—MICROBIOLOGY AND MACROBIOLOGY (EXPLORATORY INVESTIGATIONS)

### MICROBIOLOGY AND MACROBIOLOGY EXPERIMENTS

One category of experiments which is compatible with the exposure module and which would provide basic data for medical and space manufacturing applications is related to the effects of the space environment on fundamental microbiological and macrobiological processes. Past and planned biological programs, including those of Biosatellite, Gemini, and Skylab have been, or will be, limited to at most a few weeks of exposure, with severe weight and volume constraints and

limited sample quantities. In contrast, the free flying exposure module can offer a 6-to-9 month continuous exposure time for a wide range of biologicals to various combinations of zero "g", vacuum, and radiation without the weight and volume constraints in the present day biological experiments. Whereas the present day orbital experiments can expose on the order of 100,000 biological samples with ingenious packaging configurations, the space shuttle, through the exposure module, is able to offer biologists opportunities for exposing literally millions of biological samples.

The following contains a list of potential experiments that have been identified.

#### GOALS AND OBJECTIVES FOR THE 1980'S

The general goal will be to perform large numbers of basic exploratory microbiology experiments in a very inexpensive mode. The general objectives will be to obtain basic data on life forms in space and the effects of the space environment on these life forms and to generate basic data on biological related processes in space which may have future economical or social benefits.

#### POTENTIAL CONTRIBUTIONS OF THE SORTIE MODE

Preliminary studies indicate that a large number of simple biology-related experiments are desirable and can be cheaply and efficiently performed in space on an exposure module which can be transported into space, left free-flying for periods of time, and returned to ground-based laboratories for observations and analyses.

Examples of such experiments are the following:

- Kinetics of Spore Germination — Objective: To evaluate a well-characterized model for assessing the effect of zero "g" on the function of enzymes.
- Kinetics of Enzyme Activity — Objective: To evaluate the kinetics of conversion of glucose to starch with an enzyme attached to an inert carrier under the influence of a zero "g" environment.
- Insect Development and Differentiation — Objective: To evaluate the long-term effect (6 months) of a zero "g" environment on the development and differentiation of Tribolium confusum, the flour beetle.

- Evaluation of New Life Detection Concept — Objective: To evaluate the performance of a life-detection method based on the electrical conductivity of microbial soil suspensions in the zero "g" environment.
- Detection of Life in Meteoroids — Objective: Self explanatory.  
  
Comment: Not feasible unless the internal heat caused by meteoroid impact can be dramatically reduced.
- Fermentation of Phenols by Actinomycetes — Objective: To demonstrate cellular growth and yield enhancement under zero "g" conditions.
- Evaluation of Photoreactivation in the Space Environment — Objective: To measure the occurrence and extent of photoreactivation of Bacillus subtilis in the space environment.
- Nature and Frequencies of Genetic Mutations — Objective: To determine the frequencies of reversion of auxotrophic mutations in Bacillus subtilis and characterize the nature of the revertants under the space environment.
- Physical and Biological Characteristics of Microbial Aerosols — Objective: To determine the physical and biological decay processes and stability of microbial aerosols in the zero "g" condition.
- Adaptation of Thermophilic and Psychrophilic Enzyme Systems — Objective: To analyze the conformational structures of enzymes of thermophilic and psychrophilic cultures in the zero "g" environment.
- Analysis of Enzyme Kinetics — Objective: To evaluate the function of RNA-ase in solution in space environment.
- Motility of Micro-organisms, Chemotaxis and Phototaxis — Objective: To compare the chemotactic and phototactic behavior on the motility of micro-organisms in the zero "g" environment with ground controls.
- Differentiation and Development of the Sea Urchin — Objective: To compare the long-term effect of zero "g" on growth and development of the sea urchin.
- Differentiation and Growth of Plant Cellulose Tissue — Objective: Same as above.

- Kinetics of Antibody Formation — Objective: To evaluate the rate and amount of antibody produced from single cells under the effect of a zero "g" environment.
- Characterization of Porphyrin Structure — Objective: To compare the rate of synthesis and conformational structure to porphyrins in the zero "g" environment.
- Kinetics of Lysosome Deterioration by Antigen-Antibody Complexes — Objective: To compare the rate of deterioration of lysosomal membranes by antigen-antibody systems under zero "g" conditions.

#### SORTIE MISSIONS

(Same as above, see Appendix F for outline.)

#### PROPOSED FLIGHT SCHEDULE

- 1979
- 1981
- 1984

#### DISCIPLINE AREA—MATERIALS, COMPONENTS AND SYSTEMS EX- POSURE EXPERIMENTS

The free-flying exposure module provides an ideal low-cost approach to testing and determining the effect of the space and shuttle environment on materials, components and systems experiments. Many of these experiments are passive, requiring only ground-based analysis of the returned experiments. Some of the examples of experiments which follow do require power but not excessive amounts. With the low-cost aspect of space shuttle operation many of the experiments listed look attractive from the standpoint that a high failure risk can be tolerated if the particular experiment payoff is high enough. Another advantageous aspect of a low cost space shuttle operation is apparent for experiments which must be run a large number of times to establish a result in a statistically significant manner.

## GOALS AND OBJECTIVES FOR THE 1980'S

The broad goal will be to perform engineering tests of the effects of the near-earth space environment upon materials, coatings, components and some simple systems using very simple, low-cost, and near-passive exposure modules. Engineering tests of the effects of the shuttle-induced environments on these materials will also be investigated.

### SORTIE MODULE CONTRIBUTIONS TO MATERIALS, COMPONENTS AND SYSTEMS EXPOSURE EXPERIMENTS

Sortie missions to deliver into space and later Sortie missions to retrieve from space large, simple, very inexpensive and, in some cases, near-passive exposure modules will provide a unique and cost-effective approach to the investigation of the effects of the combined space environment on materials, components and systems which are planned for exposure in space on later missions for prolonged periods. The effects of the shuttle-induced environments on these materials can also be investigated by this approach.

The majority of the individual components of the space environment are thought to be simulated reasonably well in the laboratory. For example, chambers are available which can be evacuated to pressures very near the pressure which exists in near-earth space. Solar simulations are available which can very nearly simulate the solar radiation in the infrared, visible, and ultraviolet energy spectrum.

A number of facilities exist to simulate the electron and proton radiation found in space.

Facilities also exist which can combine several components of the space environment simultaneously. No facilities exist, however, which can simulate simultaneously and exactly all of the components of the space environment; thus the combined effects of all the environments may be missed in laboratory studies.

Exposure module experiments can provide a means to perform exposure experiments in the combined space environment. Data from such experiments performed on the module will be valuable as anchor-type data for evaluating laboratory test results and as final proof-type data for the performance of materials and systems in space.

Many future payloads and experiments which may be launched, serviced, and retrieved, or in some other way exist in space in the near proximity to shuttle

vehicle operations, will be critically affected if any surfaces are contaminated. Optical viewing ports, mirrors, solar cells, thermal control surfaces are, to name a few, the types of surfaces which can be damaged by contamination. It is desirable to establish what types and levels of surface contamination may result from the operation of shuttle systems such as the attitude control jets and propulsion jets.

The exposure module can carry experiments to establish what contamination, if any, results from the shuttle operation required in the launch and recovery of the module. The module can also carry experiments to monitor the contamination that results during ground handling and while in the cargo bay during launch and during the return trip from orbit.

## SORTIE MISSIONS

Specific examples of experiments which may be carried out with an exposure module cover the areas of dosimetry, changing of insulators, exposure of electronic sensors, circuits and systems, zero gravity, material surface behavior and space environment effects on foods and their containers. They include the following:

- Dosimetry — Objective: Provide complete dosimetry for UV, charged particles, heavy ions, and temperature at various points on the module. Contaminant monitoring should also be included in this effort.
- Contaminants in the Shuttle (module) Environment — Objective: To determine the gas environment in the vicinity of the module surface. This should include a determination of the normal environment as a base line; however, contamination of the near-module environment by operation of the shuttle craft or self-contamination remaining from launch and/or ground activity should receive primary attention.
- Dosimetry and Registration of High-Z Tracks — Objective: To further develop and study devices and techniques for monitoring the incidence of hi-Z particles, ultraviolet and other ionizing radiation. Techniques will include: registration of tracks in large AgCl crystals; study of hi-Z recording by etch pitting in exposed plastics and other monitor of ultraviolet; formation of color centers in various alkali halides.
- Shuttle (Instrument) Skin Temperature Patterns High-Resolution Temperature Patterns — Objective: Obtain shuttle and shuttle payload temperature patterns. Provide automatic temperature controls if needed.



- ⑥ Contaminant Detection and Removal — Objective: To characterize and "clean" the shuttle microatmosphere.
- ⑥ Space Radiation Effects in MOS Devices — Objective: Analysis of the effects produced in state-of-the-art MOS devices and special radiation-resistant MOS test structures by the space radiation environment.
- ⑥ Charging of Insulators — Objective: To study the charge build-up in insulators in the space environment. Both the rate of build-up and the possibility of spontaneous breakdown due to the charge build-up are of interest.
- Exposure of Micrometeoroid Detectors to the Space Environment — Objective: Expose capacitor-type, gas-type, and momentum-type micrometeoroid detectors to the space environment. After return, analyze effects of the space environment upon operational characteristics; examine for impacts and/or failure modes which negate their use on long-term missions.
- The Influence of the Space Environment on Contemporary State-of-the-Art Electronic Devices — Objective: To test off-the-shelf, state-of-the-art, electronic devices in a real space environment. This would include digital as well as analog devices. Typically, read-only memories, light-emitting diodes, solid state lasers, microwave transistors and diodes, large-scale and medium scale integration assemblies, and various MOS-FET units will be considered.
- ⑥ Solar Cell Evaluation — Objective: To test and analyze exposure of various solar cells to the orbital environment in order to ascertain their relative performance in space as well as to examine for degradation modes after recovery. A high-voltage array will be included in the test.
- Zero-Gravity Experiment with Superhigh Molecular Weight Polymers — Objective: To prepare superhigh molecular weight hydrocarbons such as polyethylene and polypropylene.
- Zero-Gravity Experiments - Superconducting Compounds — Objective: To examine experimentally the possibilities of synthesizing high temperature-layered superconductors.
- Solidification Under Zero Gravity (Application to Thermal Capacitor Design) — Objective: To determine if solidification of materials (metals and non metals) under a zero gravity environment is different from that occurring under normal circumstances in terms of the general morphology of the structure.

- Study of Wetting Phenomena in Metals and Ceramics — Objective: To determine the effect of zero gravity and low vacuum on the behavior of various liquids on solid surfaces. Various materials can be melted on metallic surfaces and wetting ability studied by measuring contact angles and determining surface energies.
- Rotating Condenser for Zero Gravity — Objective: To determine whether a rotating condenser offers advantages over a vapor-sweep condenser in a zero-gravity environment.
- Moisture and Heat Transport in Zero Gravity — Objective: To determine the effect of zero gravity on the transport of moisture and heat through textile materials to a controlled temperature and humidity atmosphere.
- Friction Adhesion and Wear in a Space Environment — Objective: To determine the long time effects of a space environment on the friction, adhesion, and wear characteristics of surfaces.
- Work Function — Objective: To determine the behavior of charge-emitting surfaces in the orbital environment as influenced by surface potential.
- Surface Migration — Objective: To determine the degree of atomic migration which is experienced in an orbital environment on the surfaces of solids. Stresses will include structural stress as well as electric and magnetic forces.
- Evaporation/Sublimation of Solids — Objective: To obtain data on the evaporation/sublimation of solids in the orbital environment employing a variety of materials and forms of these, e.g., single crystals and films.
- The Influence of the Shuttle Environment on Optical Components — Objective: To study the effects of prolonged exposure to near-earth environment upon components of an optical system. The optical system may be either passive (astronomical) or active (laser communications). The components of primary interest are: optical coatings for lens and mirrors; open photo-multipliers; solid state lasers.
- A Study of Plastic and Welding Behavior of Body-Centered Cubic and Hexagonal Close-Packed Metals Embrittled by Interstitial Atoms (Titanium, Zirconium, Molybdenum and Columbium) — Objective: To embrittle the proposed metals (Titanium, Zirconium, Molybdenum and

Columium) with certain levels of interstitial atoms (Oxygen, Hydrogen and Nitrogen); to expose these materials to prolonged vacuum at elevated temperatures and determine the ability of the space vacuum to remove the interstitial atoms and reduce the embrittlement: To determine this improvement by studying the plastic-behavior creep testing, tensile testing and microstructure examinations would be done.

- Thermal History of Textile Materials in Space Environment — Objective: To determine temperature maxima reached by fabrics with various thickness and emissivity/absorptivity and reflectivity characteristics.
- Production of Point Defects at Low Flux of Incident Radiation — Objective and Justification: The fates of vacancies and interstitials produced by energetic collisions depends on the dose rate. The present set of experiments aims to explore several types of systems under long-time exposure at low dose rates. Experiments would include:
  - a. production of short-range order and long-range order in low atomic weight alloys under irradiation at relatively low temperatures, ( $T < 400^\circ \text{K}$ ). The production of point defects by knock-on events would enable the system to approach equilibrium. The processes would be monitored by measurement of electrical resistivity of wire specimens, before flight and after.
  - b. growth and shrinkage of dislocation loops, voids, and stacking fault tetrahedra in quenched metal foils.
  - c. study of optical properties of transparent ionic crystals of the type:  $\text{MgO}$ ,  $\text{CaF}_2$ , and doped  $\text{CaF}_2$ , where defects are produced by knock-ons.
- Long Term Radiation Aging of Adhesives — Objectives: To determine possible chemical changes that occur in high temperature as well as cryogenic adhesives such as polybenzi-midazoles, polyimides, and epoxy with age in a high radiation flux environment such as the Shuttle's.
- Irradiation Effects on Synthetic Polymers — Objective: To determine the effect of various types of irradiation (UV-visible, low and high energy) on the structure and properties of polymers.
- Shuttle-Unique Environment Experiments with Composites — Objective: To fabricate superior strength graphite, quartz, and asbestos-fiber reinforced high-temperature resin composites.

- Shuttle-Unique Environment Experiments Involving the Crosslinking of Polyethylene — Objective: To seek a parallel in hydrogen plasma generated UV and outer space UV effects. If successful, a UV dosimeter could then be designed.
- Food Packaging Materials — Objective: To determine changes in chemical composition and structure of typical food-packaging materials and to look for possible relationships with changes in the foodstuffs. Radiation degradation of packaging materials in the presence of foodstuffs, synergistic effects, and changes in mechanical properties of packaging materials will all be looked into.
- Moisture Transfer and Microbiological Fermentation of Dry and Semi-Dry Food Products in the Space Environment — Objective: To determine the degree of moisture transfer and microbial fermentation in dry and semi-dry food products during extended storage in the space environment.
- Effect of Space Environmental Storage on Food Preservation Systems — Objective: To determine the relative effect of various food preservation systems on the quality of food products stored in the space environment.
- Food Product Packaging Materials for Space Storage — Objective: To determine the effect of various packaging materials on the quality of food products stored in the space environment.
- Effect of Space Environmental Storage on Various Classes of Foods — Objective: To determine the effect of a semi-controlled space environment on the chemical and physical properties of selected types of food products during an extended storage time period.
- Gas Permeation — Objective: To determine the permeation rates of gases through various materials which are employed in space structures.

#### SORTIE MISSIONS

(Same as above, See Appendix G for outline.)

#### PROPOSED FLIGHT SCHEDULE

- 1979
- 1981
- 1984

## SHUTTLE-BORNE ENTRY TECHNOLOGY EXPERIMENTS

The Shuttle operational era will herald an unprecedented opportunity for finally answering many elusive questions relating to entry research, e.g., boundary-layer stability. Opportunities will exist in three distinct levels of sophistication and cost:

- The first level relates to those experiments which can be conducted on a minimal or no-impact basis during each Shuttle mission as desired. It is imperative that the agency begin preparation to exploit the opportunities afforded by the Shuttle to provide the long-sought answers to fundamental problems at extremely low cost.
- The second level or class of experiments will capitalize on available excess volume within the payload bay. This volume could be utilized either for housing instrumentation or for transport of small research entry vehicles. In the case of the entry vehicle, this additional payload would be carried piggyback without impacting upon the primary mission goals, thus achieving orbit with no launch cost.
- The third level of complexity is represented by a major advanced entry vehicle which would fill completely the available cargo volume.

Activity in the area of Shuttle-borne entry technology experiments is in a formative stage. The most desirable individual experiments and the complete feasibility of conducting these experiments including the required SR&T, are presently not defined.

### LEVEL 1 EXPERIMENTS

The primary areas of opportunities here are for significant advances in the knowledge of flow fields, particularly at hypervelocity speeds, and for the research and development necessary for verification of new materials and/or techniques for thermal protection.

#### Flow Fields

Experimentation on a no-impact basis can offer increased understanding of real gas flows, boundary-layer transition and the associated heating, Reynolds number effects, lee-side flow, and others. Selected instrumentation, including

sampling probes and pressure and temperature measurements, can be made in limited, carefully chosen areas without compromising the primary goal of this phase of the mission, to wit: safe entry and landing.

A typical example of the simple, yet very meaningful experiments which will be possible is provided by the photographic mapping of smoke streamers over the lee side surface (a smoke generator and escape port will be required near the canopy and camera ports near the aft end of the vehicle).

#### Material Verification

New materials such as radiative metallic skins can be located in selected panels (with proper backup) for actual flight test verification.

#### Thermal Protection Techniques

Active cooling system schemes such as transpiration cooling could also be checked in selected locations. In addition, forced coolant procedures such as the cooling by cryogenic liquid hydrogen, crucial to the development of a hypersonic transport, could be verified.

These examples are not inclusive but merely typical of the many vital experiments that may be conducted through the capability provided by the shuttle that are crucial to the development of atmospheric flight. As it is necessary to begin to capitalize on the opportunity for space research in orbit in the shuttle area, preparations should also begin now to make the most of the opportunities afforded by each shuttle ascent and entry.

### LEVEL 2 EXPERIMENTS

Here subscale models would be used to study a wide range of flow field and material response phenomena. Most models would be unpowered and deployed for entry from the shuttle. Some would have small rocket motors to allow trajectory shaping. These models would be small enough to be "piggyback" experiments that would utilize that portion of the shuttle payload not required by the prime mission payload.

The piggyback approach is particularly amenable to investigation of advanced heat shield concepts, interference flow fields and heating, pressure distributions, and performance stability and control studies.

Flight test models would be used to obtain data on basic gas dynamic phenomena that cannot be obtained in ground tests. For example, accommodation coefficients could be measured for low-density flows past different virgin surface materials. Boundary layer transition at high Mach numbers could be measured with Reentry F-type vehicles to extend the data to a wider range of surface-to-free stream temperature ratios, Mach numbers, and pressure gradients. Data could be obtained indicating the effects of mass addition on transition.

### LEVEL 3 EXPERIMENTS

This category of experiments requires a dedicated shuttle mission to place experimental vehicles in near-earth space allowing a complete reentry flight sequence. The capability for flying large scale experimental vehicles can provide relatively inexpensive proof of concept testing as well as more fundamental information. Included would be vehicles representative of advanced transportation systems, possibly employing variable geometry features, unmanned vehicle development, possibly long-duration controllable atmospheric sampling vehicles, sophisticated military decoys, and reconnaissance concepts.

In addition, a kick stage could be carried in the bay for additional velocity to permit supercircular entry. Pressure and heating rate distributions could be measured on simple shapes which lend themselves to theoretical analyses. Thus, experimental data, free from tunnel effects, could be obtained for direct comparison with theoretical predictions.

Further, by using a kick stage a "benchmark" radiative heating experiment could be carried out. Radiative flow-field theory has reached a high stage of development and sophistication but no really definitive data are available for comparison. The need for such data has long been recognized but the high cost of flight tests (Titan III size launch vehicles are required) has been prohibitive. It would be possible to carry a propulsion system piggyback with a relatively small model and accelerate the vehicle to speeds on the order of 45,000 fps to acquire the required data.

### CONCLUDING REMARKS

#### SUMMARY OF POLICIES AND PROCEDURES RECOMMENDATIONS

1. Documentation must be simplified, with CV-990 procedures as a goal.

2. Procedures for experiment approval must be simplified utilizing the National Facility approach.
3. R&QA requirements must be evaluated relative to streamlining policies, relaxing standards, and simplifying procedures. Early standardization of modular equipment specifications is required so that users can purchase experimental equipment for use in ground laboratories and, subsequently, use the same equipment in shuttle missions.
4. Hardware turnover should be minimized. The user should be responsible for his experimental equipment from initial purchase through installation and checkout in the Shuttle/Sortie Laboratory.

#### SUMMARY OF SORTIE MISSION REQUIREMENTS

1. The debris which could be introduced to the local external environment of the shuttle by the release of restraining clamps, payload deployments and associated pyrotechnics must be eliminated, controlled, or at least minimized.
2. The shuttle internal payload bay wall temperature may reach 200° F during entry and postlanding. This high temperature will surely compromise some experimental payloads within the payload bay. Cost tradeoffs should be made relative to reducing Shuttle payload bay temperature versus any additional insulation/cooling required for experiments.
3. Dumping of water and other effluents must receive serious attention relative to eliminating or alleviating contamination problems.
4. Remote manipulators are required. In one case, the manipulator boom must apply 200 pounds of tip force.
5. Advanced power and propulsion systems development requirements (AEC/NASA) exceed current Shuttle capability to handle radiation and thermal loads. The Shuttle should be compatible with satellite power, both solar and nuclear RTG or reactors, and with high energy propulsion stages, including advanced chemical, solar electric, nuclear electric, and small nuclear rockets now being studied for geosynchronous and planetary missions for the 1980-1990 time period. The Sortie mode should be utilized to define Shuttle cooling and radiation shielding requirements as well as to demonstrate rendezvous and handling for radio-active or thermally-hot payloads and propulsion systems.



## SUMMARY OF SUGGESTED FUTURE ACTIVITY

1. The small, informal, user working groups should be continued. However, the user working groups will be more productive if they can get together with the Shuttle and Sortie Laboratory designers (MSC and MSFC engineers) for direct designer-to-user discussions and data exchanges.
2. Additional active researchers with new ideas should be encouraged to participate in working groups. An attempt should be made to shift from managerial level participants to those individuals who have already submitted, or are prepared to submit, specific, definitive, Shuttle experiment proposals.
3. A reasonable level of funding must be provided now to permit the definition and development of experiments that are currently being proposed for Shuttle Sortie missions. Otherwise, the principal investigators will lose interest in proposing or developing experiments for Shuttle payloads, and the agency could find itself ready to fly Shuttle missions and not have a reasonable backlog of experimental payloads available.
4. The NASA user presentations should be made to NASA management and the Manned Space Flight Program Office before exposure to the scientific and engineering communities of other government agencies, universities, and industry.
5. The results of the recent NASA Space Research and Technology (SPART) study should be reviewed and utilized where applicable.
6. Inputs from the other working groups are particularly important to the Space Technology Working Group, e.g., technological and operational requirements.
7. Because of the relationships of fundamental physical principles to many technology areas, this working group considered physics and chemistry experiments in space. However, it was concluded that because of the potential for Sortie experiments in this discipline a separate discussion be dedicated to this effort. Therefore, the chemistry and physics documentation is submitted separately.
8. It is recognized that advanced technology activities are divided into two categories. The first is concerned with providing the design data needed to accomplish future space missions and includes spacecraft subsystems

such as environmental control and life support, stability and control, electrical power, propulsion, navigation, guidance, communications, and related structures, materials and instrumentation. The second category is concerned with research on basic phenomena required as a foundation for the design of subsystems and components and research which adds to the general body of scientific and engineering knowledge. It appears logical for the Space Technology Working Group to spawn additional groups or subgroups composed of individuals conducting research in the previously mentioned advanced technology areas. As an example, a discussion of Shuttle-Borne Entry Technology Experiments has been included in this report.

The overlap of advanced development activities of a singular discipline working group and those of an advanced space technology working group (where single efforts often benefit many disciplines) must be recognized and accounted for by division of responsibility in order to avoid costly duplication of efforts.

#### SEPARATE DISCUSSION OF A PHYSICS AND CHEMISTRY LABORATORY IN SPACE

At the Shuttle Sortie Workshop, physics and chemistry experiments in space were included in the Working Group on Space Technology. After discussions by the working group it was concluded that because of the magnitude and scope of the current studies for a Physics and Chemistry Laboratory in Space, and because of the potential for a substantial number of Sortie experiments in these disciplines, a separate discussion should be devoted to this effort. Therefore, this report is being submitted separately from the report of the Space Technology Working Group. (This report was prepared by Mr. John P. Mugler, Jr., LaRC, and Dr. M. M. Saffren, JPL.)

See Appendix H for further discussion of the Physics and Chemistry Laboratory.

#### GOALS AND OBJECTIVES

The objective of the current study under RTOP 975-73-48 is to define concepts for physics and chemistry experiments in space and to develop a small number of these concepts to the point that experiment definition studies can be initiated. The study is being conducted by a study team which is composed of representatives from NASA Headquarters, LaRC, LeRC, MSFC, JPL, GSFC, MSC, and the National Science Foundation (NSF). Candidate physics and chemistry experiment concepts have been solicited from NASA Centers and JPL. These

experiment concepts will be reviewed and evaluated by an Ad Hoc Advisory Panel composed primarily of members of the NSF Physics and Chemistry Advisory Panels. Experiment concepts with the greatest scientific merit will be funded for further definition and development. These initial studies will not only supply candidate experiments for early Sortie missions but also will serve as examples in our subsequent solicitation of physics and chemistry experiment proposals from the scientific community at large.

## POTENTIAL CONTRIBUTIONS

### Physics and Chemistry Laboratory in Space

The Laboratory will support a wide range of original physics and chemistry experiments in facilities listed below, which take advantage of the unique environmental conditions in space and which are either impossible or impractical to carry out on earth. It is planned that each facility be self contained so that it can be flown on any available Sortie mission.

## DESCRIPTIVE TITLES OF FACILITIES

As presently envisaged, the Physics and Chemistry Laboratory will not be a dedicated laboratory but instead will consist of modules or facilities which can be flown on available Sortie missions. It will consist of: a wall-less chemistry Neutral and Molecular Beam facility; a Superfluid Helium and Drop/Particle facility; a Neutral Beam facility; and a Fluid Physics and Heat Transfer facility.

## EXPERIMENTS RECOMMENDED FOR FACILITIES

### Wall-Less Chemistry and Molecular Beam Facility

- Gas Chemistry Experiments in Space — Objective: To produce and study long-lived gaseous metastable species which are ordinarily lost to vessel walls on earth; formation of excited species by irradiation by sunlight at orbital height.
- Mass and Energy Analysis of Neutral Species — Objective: Use of a simple energy analyzer to determine the composition and "temperature" of neutrals at orbital height. This determination is needed to understand the environment of neutrals in which shuttle gas chemistry experiments will be performed.

- Flame Chemistry — Objective: Generation of large mixed flames to study flame reaction in a detailed way that is impossible to duplicate on Earth where the vacuum chambers required for such flames would be impractical.
- Ion Beam Experiments — Objective: Study of low yield electron-ion neutralization processes by means of both crossed and merging beam experiments. On Earth these low yield experiments cannot be performed because electron neutralization is masked by neutralization from charge transfer to background gases which are virtually impossible to remove from earth-based experiment chambers.

#### Superfluid Helium and Drop/Particle Positioning Facility

- Quantum Effects in Superfluid Helium — Objective: Superfluid helium drops suspended in weightlessness will be used to study the formation of quantized vortices in superfluid helium, as well as other properties of helium, in the absence of container walls.
- Drop Dynamics and Accretion Studies — Objective: Several experiments in drop dynamics and accretion of particulates and of droplets will be performed, among which are: coalescence of drops (water drops); ice crystal formation; formation of free crystals from vapor; condensation and evaporation of drops; surface tension driven flows in fluids; study of the coupling of oscillation and vibration modes in drops; and motion of drops in thermal gradients.
- Condensation of Gases into Solids — "Inverse Sublimation" — Objective: To study condensation of vapors into freely suspended grains, and condensation of vapors into solids in the absence of supporting substrates.
- Effects of Collisions on an Aggregate of Orbiting Particles — Objective: To study the conditions required to form a jet stream in an aggregate of orbiting particles; to study the dynamics of a system of orbiting particles undergoing collision.

#### Fluid Physics and Heat Transfer Facility

- Combustion in Zero Gravity — Objective: To use the long-term near-zero gravity environment to study the basic chemistry and mass transfer mechanisms in combustion processes. The results will complement current zero gravity experiments being conducted in drop towers for short test times and will extend the data to the point that realistic mathematical models of combustion phenomena can be developed.

- Critical Point Phenomena — Objective: To use the long-term near-zero gravity environment to obtain the equilibrium and transport properties of fluids in the region of the critical point. These experiments will provide the first results, free of large gravity-induced compressibility effects, in the critical region.
- Pool Boiling at Low Gravity — Objective: To determine the conditions under which nucleate boiling in saturated liquids can be sustained in near-zero gravity. The results will contribute to a more complete understanding and mathematical description of boiling phenomena.
- Crystal Growth — Objective: To study the effect of compositional and thermal gradients on the growth of crystals, taking advantage of the absence of convective mixing in zero "g".

#### Neutral Beam Facility

- Gas-Surface Interactions — Objective: To use the flux of atomic oxygen available only in space to study the physical and chemical interactions of oxygen with solid surfaces.

#### SCHEDULE

A meaningful experiment program in the 1980's and late 1970's demands an aggressive development of candidate experiment concepts and an intense experiment definition effort that must begin now.

The authors estimate that each of the four facilities noted above would be required to fly once a quarter. This may be a conservative estimate, however. As new areas of research open up as a result of experiments performed on early missions, the interest of the scientific community can be expected to grow. Consequently, more missions will have to be flown, perhaps as much as one mission a month for some of the facilities.

APPENDIX A  
ADVANCED TECHNOLOGY LABORATORY

DISCIPLINE AREA--ADVANCED TECHNOLOGY LABORATORY

SORTIE DESCRIPTIVE TITLE

Multidiscipline Advanced Technology Research and Development Experiments

REASONS SORTIE MODE PREFERRED

The Sortie mode is preferred over other methods for each of the potential contributions because all of the presently-proposed experiments can be performed during a 7-day, or longer, Sortie mission. The nature of the research embodied within these experiments generally requires evaluation of experimental results so that, if needed, experimental equipment and/or procedures can be modified prior to their inclusion in a future Shuttle Sortie mission. Therefore, repetitive 7-day, or longer, Sortie missions appear to be the most economical method to utilize space to accomplish the experimental objectives. Experiment accommodation was previously discussed in the paragraph entitled "Required Sortie Missions."

REQUIREMENTS ON SHUTTLE

The requirements listed here are for the three previously discussed ATL payloads. (See Table A-1 for experiment coding.)

Payload Number One (P/L No. 1)

Includes experiments CN-1, -2 and -4; PH-1, -3, -4, -5 and -6; EO-3; MB-1, -2, -3, -4 and -5; CS-1 and -2; and EN-1, -2, -3 and -4.

Payload Number Two (P/L No. 2)

Includes experiments CN-3, -5, -7 and -9; PH-1, -2, -4 and -5; EO-1, -2 and -4; MB-1, -2, -3 and -4; CS-1 and -2; and EN-2, -3 and -4.

Payload Number Three (P/L No. 3)

Includes experiments CN-6, -8 and -9; PH-1, -3, -4, -5 and -6; EO-1, -2, -3 and -4; MB-1, -2, -3 and -5; and EN-1, -2 and -3.

### Length of Flights

7 days minimum.

### Orbit

Altitude of 200 nm and inclination angle of  $60^\circ$  for P/L No. 1. Altitude of 300 nm and inclination angle of  $60^\circ$  for P/L No. 2. Altitude of 100 nm and inclination angle of  $90^\circ$  for P/L No. 3.

### Data Requirements

Average data requirements = 400,000 mb/day for P/L No. 1, 600,000 mb/day for P/L No. 2, and 320,000 mb/day for P/L No. 3. Preliminary analysis indicates that the Shuttle Sortie Laboratory data management subsystem is marginal to support the ATL experiment requirements.

### Role and Number of Personnel in Orbit

Total crew time requirements = 126 hours for P/L No. 1, 122 hours for P/L No. 2 and 125 hours for P/L No. 3. No highly skilled specialists are required. However, broad crosstraining will be required for the crewmen to achieve a reasonable skill level in the areas of electronics, meteorology, photography, optics, physics, microwave technology and microbiology.

### Stabilization and Pointing

Pointing stability of  $\pm 0.5^\circ$  is required for 64 hours for P/L No. 1, 73 hours for P/L No. 2, and 55 hours for P/L No. 3. Pointing hour requirements are based on viewing opportunities of selected targets. A time buffer of 25 minutes is included for each viewing opportunity to allow 15 minutes for warmup, plus 5 minutes on standby, prior to the actual viewing period to acquire data, and 5 minutes for shutdown at the end of the data acquisition period. Preliminary analysis indicates that the Shuttle Sortie Laboratory stability and control subsystem is marginal to support the ATL experiment requirements.

### Power and Thermal

Total electrical energy requirement = 208 kw hours for P/L No. 1, 291 kw hours for P/L No. 2 and 331 kw hours for P/L No. 3. Preliminary analysis indicates that the Shuttle Sortie Laboratory thermal control subsystem is marginal to support the ATL experiment requirements. Solutions are being sought to this apparent problem of heat rejection capability available for payloads.

### Weight and Volume

Total weight = 3927 lbs for P/L No. 1, 8320 lbs for P/L No. 2, and 8583 lbs for P/L No. 3. Total internal pressurized volume = 270 cu ft for P/L No. 1, 526 cu ft for P/L No. 2, and 417 cu ft for P/L No. 3. Design layouts indicate that experimental equipment to be installed in the unpressurized pallet area can be accommodated on a 30 ft pallet for each of the three payloads as shown in Figure A-1.

### EVA Requirements

None.

### Correlative Measurements

Coordination with ground truth sites is required to develop the experimental technology for several experiments. Fixed or mobile ground stations will be required.

### General Support Equipment

To be determined.

### Documentation Requirements

Minimum.

### Special Operating Constraints

No thermal dumping near deployed booms. Some externally deployed experiments sensitive to contamination by the Shuttle Sortie Laboratory. Some experiments are acceleration sensitive.

### Contamination Requirements

See above.

## POLICIES AND PROCEDURES

Individual experimenters must have responsibility for the successful operation of their experiment. If the Shuttle Sortie Laboratory is to provide easy access to space for low-cost payloads, the documentation, training and R&QA requirements must be held to a minimum.



## ESTIMATED MAGNITUDE OF SORTIE USER COMMUNITY

Substantial user community composed of researchers in NASA, industry, universities, and other government agencies.

## RECOMMENDED APPROACHES FOR INTERFACING WITH THE USER COMMUNITY

Solicit user community in science application, exploration, and transportation for technology requirements.

## RECOMMENDATIONS ON FUTURE ACTIONS

A reasonable level of funding must be provided now to permit the definition and development of experiments that are currently being proposed for Shuttle Sortie missions. Otherwise the P.I.'s will lose interest in proposing or developing experiments for Shuttle payloads and the agency could find itself ready to fly Shuttle missions and not have a reasonable backlog of experimental payloads available.

Table A-1

### ATL Experiments

#### COMMUNICATIONS AND NAVIGATION

- CN-1 Microwave Interferometer Navigation and Tracking Aid
- 2 Microwave Radiometer Measurements
- 3 Precision Laser Ranging and Altimetry
- 4 Autonomous Navigation
- 5 Microwave Altimetry
- 6 Search and Rescue Aids
- 7 Multipath Measurements
- 8 Imaging Radar
- 9 RF Noise

#### EARTH OBSERVATIONS

- EO-1 Lidar Measurements of Cirrus Clouds and Lower Stratospheric Aerosols
- 2 Tunable Lasers for High Resolution Studies of Atmospheric Constituents and Pollutants
- 3 Multispectral Scanner for Coastal Zone Oceanography
- 4 Shuttle Delivery of Atmospheric and Oceanographic Ground Truth Payloads

Table A-1 (continued)

PHYSICS AND CHEMISTRY

- PH-1 Spacecraft Wake Dynamics
- 2 Barium Plasma Cloud Release on Sunward Side of the Earth
- 3 Optical Properties of Aerosols
- 4 Mapping of Upper Atmospheric Neutral Gas Parameters
- 5 Spacecraft Radiation Environment
- 6 Ultraviolet Meteor Spectroscopy from Near Earth Orbit

MICROBIOLOGY

- MB-1 Colony Growth in Zero Gravity
- 2 Interpersonal Transfer of Micro-organisms in Zero Gravity
- 3 Electrical Field Capacity in Biological Cells
- 4 Electrical Characteristics of Cells
- 5 Special Properties of Biological Cells

COMPONENTS AND SYSTEMS TESTING

- CS-1 Carbon Deposition and Transport in Zero Gravity
- 2 Zero Gravity Steam Generator

ENVIRONMENTAL EFFECTS

- EN-1 Sampling of Airborne Particles and Micro-organisms in Space Cabin Environment
- 2 Orbital Fatigue Experiment
- 3 Environmental Effects on Nonmettalic Materials
- 4 Fluids in Zero Gravity

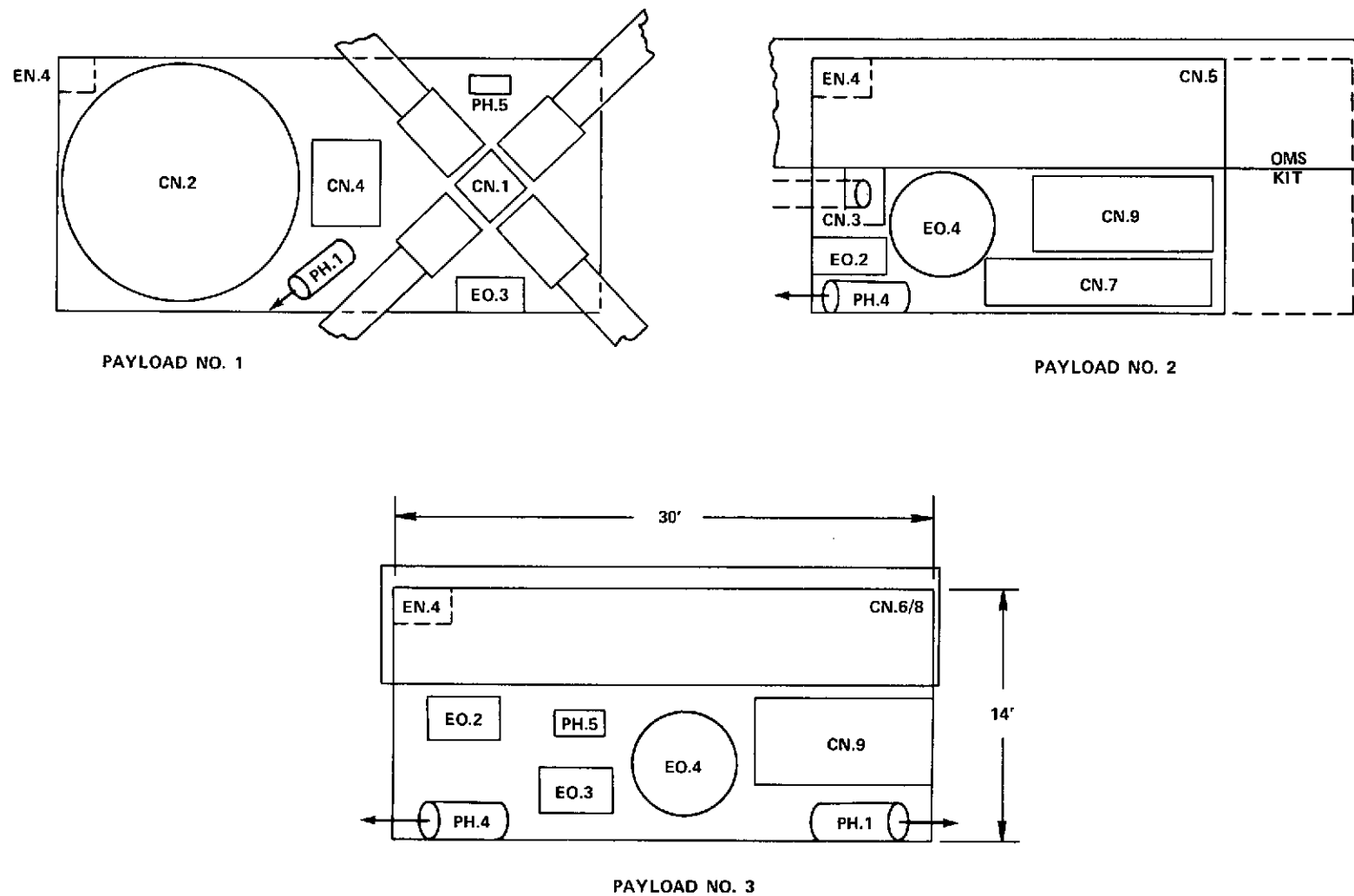


Figure A-1. ATL Experiment Payloads on 30-foot Pallet

## APPENDIX B LASER COMMUNICATIONS

### DISCIPLINE AREA — LASER COMMUNICATIONS

#### SORTIE DESCRIPTIVE TITLE

Laser Communications Experiments

#### REASONS SORTIE MODE PREFERRED

- Lower experiment cost because of capability to use some commercial rack-mounted equipment.
- Greater experiment versatility because of capability to observe data on line and to modify experiment in progress.
- Greater experiment versatility because of capability of returning payload for major modifications or experiment changes.

#### REQUIREMENTS ON SHUTTLE

- Length of Flight — Flights from 7-days duration and up can contribute to this effort. Shuttle-deployed subsatellites can be useful with a lifetime from a few weeks up to several months.
- Orbit — Not critical, although for low-earth-orbit to ground shuttle must pass over ground station.
- Data Requirements — Necessary for housekeeping, noting parameter changes, and measuring bit error rates. Cannot be defined accurately at this time.
- Role and Number of Personnel in Orbit — One or two persons in orbit to observe data, make experiment modifications and experiment parameter changes and act as general "troubleshooter".
- Stabilization and Pointing — Shuttle must be reasonably stable in order to maintain a line of sight but should use CMG's or cold gas for attitude control. Hot gas systems will contaminate an optical communications system, as it will any optical payload. The payload will provide its own precision pointing to 1 arc second or better.

- Power and Thermal — Power requirements may range from 100 watts to 500 watts depending on exact instrumentation techniques and particular experiment. Thermal not yet defined, although the synchronous orbit VLCE could serve as a model for requirements.
- Weight and Volume — 100 pounds up to several hundred depending on instrumentation techniques and cost.
- EVA Requirements — Not required except for possible pallet recovery in case of failure that can be fixed on board. Possible use of instrumentation airlock could alleviate this requirement and increase experiment versatility.
- Correlative Measurements — Spacecraft attitudes and location must be known for experiment.
- General Support Equipment — Scopes, general laboratory equipment, spectrum analyzers.
- Documentation Requirements — Not known.
- Special Operating Constraints — Attitude controlled to within limits of experiment pointing device. Could be several tens of degrees. Attitude rates not to exceed 1° per second. Attitude and location must be known.
- Contamination Requirements — Optical surfaces must be kept clean.
- Other — Unknown.

## POLICIES AND PROCEDURES

Unknown.

## ESTIMATED MAGNITUDE OF SORTIE MISSION USER COMMUNITY

Unknown.

## RECOMMENDED APPROACHES FOR USER COMMUNITY INTERFACING

1. Interface through the Shuttle Sortie lab seems reasonable. Greatest versatility would be achieved if the Sortie lab is autonomous.

2. Sortie lab should provide document of standard thermal, mechanical and power interfaces to users.
3. Shock, vibration, acoustic, humidity, and thermal qualities in the environment should be softened as much as possible to enable user to make maximum use of standard laboratory equipment.
4. It is recognized that the "g" loads caused by launch and reentry cannot be controlled; however, Shuttle Sortie lab people should develop standard means of protecting equipment during such loads and provide documentation to users for implementation into their experiments.

#### RECOMMENDATIONS ON FUTURE ACTIONS

Laser communications are presently being developed through the VCLE program. However, independent development of devices for future systems should start now, particularly laser development. As the VLCE program develops, much more information applicable to the Shuttle Sortie missions will become available.

## APPENDIX C EXTERNAL CONTAMINATION

### DISCIPLINE AREA — EXTERNAL CONTAMINATION

#### SORTIE DESCRIPTIVE TITLE

##### External Contamination Assessment and Abatement Mission

External Contamination Monitors are needed on each optical-type mission. The Controlled Contamination Release Experiment would be better deployed during the Sortie mode due to the short duration of exposure and the opportunities for quick data return.

#### REQUIREMENTS ON SHUTTLE

##### Length of Flights

Applicable to any mission duration.

##### Orbit

No restriction.

##### Data Requirements

- Telemetry from the contamination monitoring systems
- Data pertaining to the performance degradation of the optical or other systems on that particular mission
- Mission time of all ventings, RCS thruster firings, or other effluent events

##### Role and Number of Personnel in Orbit

None required if the data are returned by telemetry. If the data are displayed on a console, there is a requirement for this console to be monitored at appropriate times by one of the crew.

### Stabilization and Pointing

The stabilization of these instruments is not a factor in that they will probably be rigidly mounted to a portion of the shuttle or to a particular payload. The pointing directions will vary, depending upon whether the shuttle environment is being monitored or whether a particular optical system itself is being monitored. The pointing accuracy should be  $\pm 5^\circ$  in azimuth and elevation.

### Power and Thermal

The power requirements of all contamination-related equipment will be on the order of 500 watts steady state and 750 watts peak. The equipment will be designed to the thermal environment within which it is located.

### Weight and Volume

The contamination monitoring equipment can be grouped into a single location for which the combined weight and volume would be 50 kg and  $1 \text{ m}^3$  respectively. However, it is more probable that the equipment will be deployed as individual units for which the following would apply:

- Integrated Real-Time Contamination Monitors, (IRTCM), 30 kg and  $0.4 \text{ m}^3$ .
- Controlled Contamination Release Experiment, (CCRE), 5 kg and  $0.05 \text{ m}^3$ .
- Laser Doppler Velocimeter (PV), 10 kg and  $0.1 \text{ m}^3$ .
- Active Cleaning Technique, (ACT) 20 kg and  $0.1 \text{ m}^3$ .
- Quartz Crystal Microbalances, (QCMs), 0.2 kg and  $0.0005 \text{ m}^3$ .
- Mass Spectrometer, (MS), 15 kg and  $0.05 \text{ m}^3$ .
- Active Scattering Particle Spectrometer, (ASPS), 15 kg and  $0.1 \text{ m}^3$ .

### EVA Requirements

None required.

### Correlative Measurements

The contamination data will be correlated with the temperatures and pressures of the experiment containers being monitored.



## General Support Equipment

- Launch site — The contamination monitoring equipment will require some standard electronic test equipment such as volt meters, oscilloscopes and recorders, as well as typical laboratory tools for the installation and checkout of the flight equipment.
- Aboard the Sortie Lab — An equipment console will be required for the control and display of the data from the various monitoring instruments. Use of an onboard computer will be required to pre-condition the mass spectrometric data prior to their being displayed or relayed to a ground station.

## Documentation Requirements

It is proposed that the documentation be reduced to the absolute minimum. It is understood that a flight unit qualification will be required to ensure against fire, odor, and other contingencies.

## Special Operating Constraints

Particular monitoring equipment, when possible, should be operating just prior to launch, during launch, and during all orbital operations. The equipment is being designed to be operated with the shuttle cargo bay doors closed or opened. One of the purposes of some of the contamination monitors is to provide the information needed to make the decision to keep the doors closed or to open them. For this reason, some of the monitors should be located on the underneath side of one or both cargo bay doors.

## Contamination Requirements

The contamination monitoring instruments are being designed to monitor a deposition of  $10^{-8}$  gms of material, a particle size down to 0.1 microns, 1 part in  $10^6$  hydrocarbons ( $\text{CH}_4$  standard). Inasmuch as this equipment is being designed to monitor contamination, it has no contamination requirements itself once it has been placed into operation. However, before equipment is mated to those systems which are being monitored, it must be kept in an environment which is controlled to a Class 100 specification.

## Contamination Monitoring Equipment Descriptions

In general, this collection of experimental equipment is not available "off the shelf." However, the power supplies and signal conditioners could be standardized so that available commercial equipment could be utilized.

The following instruments are currently being defined or could be defined if the requirement is firmly established:

Integrated Real-Time Contamination Monitor (IRTCM)—The IRTCM is a collection of specific instruments mounted on a pallet which will be mounted on the inside of one or both cargo bay doors. The pallet arrangement can be utilized to add, delete, or modify the individual monitors as may be required by a particular sortie mission type. The reason for having the contamination monitoring pallet on the inside of the doors is that the induced environment of the cargo bay will be monitored before the doors are opened and will also monitor the exterior environment after opening the doors.

The bulk of the pallet is occupied by the optical effects module. This module contains a sample exposure wheel containing three optically transmissive samples, three optically reflective samples, and three quartz crystal micro-balances. The device contains a XUV source tube, a hemellipsoid, and a movable detector. The source tube produces two monochromatic lines in the XUV. The quartz crystal micro-balances are produced in such a way as to allow a reflected beam to be monitored from the same surface which is collecting deposited material. The important feature of this is that reflectance data are obtained from the identical surface which is providing mass accumulation data. The other optical samples are exposed for an amount of time which can be varied from minutes to months if needed. The exposed samples are then brought into the measuring position by rotating the sample wheel. The instrument is self-calibrating.

The other devices presently envisioned to be on the IRTCM pallet are: 1) a mass spectrometer, 2) an Active Scattering Particle Spectrometer, and 3) the Active Cleaning Technique.

The mass spectrometer is a cold cathode quadripole device having a range from 2 to 312 AMU and a sensitivity of better than 1 part in  $10^6$ .

The Active Scattering Particle Spectrometer (ASPS) is designed as a dual-laser, inner-cavity, scattered-radiation monitor using solid state detection. The system involves two laser tubes flange-plate mounted and sealed to assure integrity of the chamber atmosphere, thus avoiding the problem of corona discharge. The solid state detectors will be preceded by the gimballed composite of laser tubes, end mirror, scattered radiation collecting lense, and an appropriate truncation stop, as necessary.

The ASPS measures particles with speeds up to 50 meters per second and sizes from 0.1 microns to 25 microns in 29 direct measurement size intervals. As

an additional data output, the back DC radiation of the laser tubes, already used in the system to produce continuous calibration, will be displayed as a monitor of the deposition contamination on the exit window of the laser tubes. The ASPS is particularly suited to shuttle cargo bay contamination measurements both internally and externally and for pre-launch to orbit conditions. It is a program-med module for the proposed integrated real-time contamination monitor (IRTCM) package for the Shuttle Sortie missions.

The Active Cleaning Technique will be used as a part of the IRTCM as well as being installed as part of the in-situ maintenance equipment of large optical systems such as the Large Space Telescope (LST) or other optical systems which can use its capabilities.

The device operates by piping oxygen or other suitable gas to the contaminated surface of a mirror or filter. At the point of gas discharge, an RF coil generates a plasma which then chemically combines with the contaminant, allowing the resultant compounds to escape to the surrounding vacuum environment. The device will also contain an attachment to allow sputtering of the surface if the surface can tolerate such a procedure and if the contaminant can be removed in no other way.

Laser Doppler Velocimeter—The Laser Doppler Velocimeter (LDV) is a focused, crossed-beam, dual-scattering system utilizing two columnated beams from a single laser which can be made to focus and intersect in any sampling volume of interest. The velocimeter detects the velocity of any moving semi-transparent medium by detecting the scattered light as the particles cross the interference fringes which are set up in the beam intersection area. Since the fringe spacing is known, the rate of intermittent scatter as the particle crosses the fringes is a true measure of particle size and velocity. The velocimeter is self-aligned and self-calibrating and produces particle velocity data up to tens of kilometers per second and particle size data from less than 0.1 microns to several millimeters. The sample volume in this velocimeter will be scanned to cover the large area of the shuttle cargo bay interior, across the opening of the bay, and experiment openings and hatches. The inspection volume can be remote from the basic instrument.

Controlled Contamination Release Experiment—This experiment contains a tank of known, unique material which will be released to the environment at one or more locations and then monitored at one or more separate locations to characterize the dynamics of any induced environment.

Photometer—The Skylab contains an advanced photometer which may be appropriate for the Shuttle Sortie missions. If it is determined that a different or more specialized photometer is needed, one can be provided.

## RECOMMENDATIONS FOR CHANGES IN POLICIES AND PROCEDURES

The following changes in policies and procedures are recommended:

1. Reduce the amount of time between initiation and flight of an experiment.
2. Reduce the documentation to the absolute minimum.
3. Change the Reaction Control System on the shuttle to either a cold gas or CMG system to reduce the effluents in the environment.
4. Institute a procedure which ensures more experiments are available for flight than can be accommodated. The ones to be flown will then be those which have met cost and schedule milestones.
5. Decouple the shuttle launch schedule from the schedules of the candidate experiments.

## SORTIE MISSION USER COMMUNITY

The induced environment data to be provided by these contamination monitors, techniques, and devices will be made available to, and utilized by, those experimenters using optical telescopes, other optical systems, and critical surfaces. It would appear that at least one quarter of the Shuttle Sortie flights will require these environmental data.

## INTERFACING WITH USER COMMUNITY

The methods used on Apollo and Skylab will be continued. That is, the known users of the data are contacted directly with respect to the probable availability of the data. In turn, their requirements for specific types of contamination data are considered in the make-up of the contamination data collection system.

## RECOMMENDATIONS ON FUTURE ACTIONS

1. If certain experiments are thought to be valid for the Shuttle Sortie mode, then early funding should be approved in order to minimize the effect of funding most of the experiments at a later date.
2. Adequate SRT funds should be provided for the maintenance of the required expertise within the NASA field center which is responsible for a specific area of research. If inadequate funding is provided, this expertise will shift into other areas considered to be more important.

## APPENDIX D PARTICULATE MATTER

### DISCIPLINE AREA—PARTICULATE MATTER IN SPACE (METEOROIDS, COSMIC DUST AND DEBRIS).

#### SORTIE'S DESCRIPTIVE TITLE

Long Duration Exposure Facility

#### REASONS SORTIE MODE IS PREFERRED

The Shuttle Sortie mode is preferred first because of the return capability. Most of the active and complex measurements can be made in the laboratory after the exposure in space. The ability to observe impact damage, for example, provides much more information than automated penetration detection. The cost of the experiments is reduced by orders of magnitude.

#### REQUIREMENTS THIS TYPE MISSION PLACES ON THE SHUTTLE IF THE POTENTIAL CONTRIBUTIONS ARE TO BE REALIZED

- Length of Flights — Six to twelve months' free flying.
- Orbit — Not critical provided module has sufficient lifetime.
- Data Requirements — No telemetry — all data will be recorded on ground after exposure.
- Role and Number of Personnel in Orbit — None required other than for launch and recovery.
- Stabilization and Pointing — Not required.
- Power and Thermal — No power — module will have passive thermal control - no control required in cargo bay.
- Weight and Volume — 15,000 pounds - 14 feet in diameter by 30 feet in length.
- EVA Requirements — None.

- Correlative Measurements — None.
- General Support Equipment — None.
- Documentation Requirements — None.
- Special Operating Constraints — None.
- Contamination Requirements — None.
- Other — None.

## APPENDIX E METEOR SPECTROSCOPY

### DISCIPLINE AREA — ULTRAVIOLET METEOR SPECTROSCOPY FROM NEAR EARTH ORBIT

#### SORTIE TITLE

Sortie Laboratory Mission (one experiment on board).

#### PREFERENCE FOR SORTIE MODE

The experiments can best be performed from a manned spacecraft with recovery capability. Man is beneficial in changing films and routine sensing of the cameras and in making preliminary evaluation of spectra. The ability to return the film for ground based data reduction is also desirable.

#### REQUIREMENTS

- Length of Flights — Cumulative time in space 1 year.
- Orbit — Not critical.
- Data Requirements — Return film.
- Role and Number of Personnel in Orbit — This experiment can be highly automated. The role of man is to utilize the internal control panel to initiate the experiment and to monitor instrument performance. Only one person in orbit is required.
- Stabilization and Pointing — Stabilization not critical, but unit must point to earth on dark side and attitude must be known to  $\pm 1^\circ$ .
- Power and Thermal — Less than 1 watt average - peak intermittent power of 10 watts for 1 second duration.
- Weight and Volume — 50 lbs., 4 cubic feet.
- EVA Requirements — None.

- Correlative Measurements — Attitude of spacecraft.
- General Support Equipment — Dark-room capability on module.
- Documentation Requirements — None.
- Special Operating Constraints — None.
- Contamination Requirements — None.
- Other — None.



## APPENDIX F MICROBIOLOGY

### DISCIPLINE AREA — MICROBIOLOGY (EXPLORATORY INVESTIGATIONS).

#### SORTIE DESCRIPTIVE TITLE

Long Duration Exposure Facility (Microbiology Experiments).

#### REASONS SORTIE MODE PREFERRED

The Shuttle Sortie mode is preferred because of its return capability. Most of the active and complex measurements can be made in the laboratory after the exposure in space.

#### REQUIREMENTS

- Length of Flights — 6 months free flying.
- Orbit — Not critical provided module has sufficient lifetime.
- Data Requirements — No telemetry.
- Role and Number of Personnel in Orbit — None required other than for launch and recovery.
- Stabilization and Pointing — None required.
- Power and Thermal — None.
- Weight and Volume — 15,000 pounds - 14 ft. diameter by 30 ft. length.
- EVA Requirements — None.
- Correlative Measurements — None.
- General Support Equipment — None.
- Documentation Requirements — None.

- Special Operating Constraints — None.
- Contamination Requirements — None.
- Other — None.

POLICIES AND PROCEDURES WHICH MUST BE CHANGED TO FULLY EXPLOIT THE SORTIE MODE AND REDUCE COST

Maintain simple interface of module with shuttle and minimize testing and documentation requirements.

BRIEF ESTIMATE OF MAGNITUDE OF USER COMMUNITY

Large user community consisting of researchers in government, universities, and industry.

RECOMMENDATIONS

1. Some funding must be made available now to start module definition and to prepare experiments.
2. The interface approach to the user community should be done through NASA researchers in the field.

## APPENDIX G

### EXPOSURE EXPERIMENTS

#### DISCIPLINE AREA — MATERIALS, COMPONENTS AND SYSTEMS EXPOSURE EXPERIMENTS

##### SORTIE TITLE

Long Duration Exposure Facility (Materials, Components and Systems Exposure Experiments).

##### PREFERENCE FOR SORTIE MODE

The Shuttle Sortie mode is preferred because of its return capability. Most of the active and complex measurements can be made in the laboratory after the exposure in space.

##### REQUIREMENTS

- Length of Flights — Six months free flying.
- Orbit — Not critical provided module has sufficient lifetime.
- Data Requirements — No telemetry — all data will be recorded on ground after exposure.
- Role and Number of Personnel in Orbit — None required other than for launch and recovery.
- Stabilization and Pointing — Not required.
- Power and Thermal — No power; module will have passive thermal control; no control required while in cargo bay.
- Weight and Volume — 15,000 pounds, 14 feet diameter by 30 feet in length.
- EVA Requirements — None.
- Correlative Measurements — None.

- General Support Equipment — None.
- Documentation Requirements — None.
- Special Operating Constraints — None.
- Contamination Requirements — None.
- Other — None.

## RECOMMENDED POLICIES AND PROCEDURES

Maintain simple interface of module with shuttle and minimize testing and documentation requirements.

## ESTIMATED MAGNITUDE OF SORTIE MISSION USER COMMUNITY

Government researchers (NASA, Air Force, for example) and university personnel primarily.

## RECOMMENDATIONS

1. Some funding must be available now to start definition of module and preparing experiments.
2. The user community should be interfaced through NASA researchers in field rather than shuttle engineers.

## APPENDIX H PHYSICS AND CHEMISTRY LABORATORY

### DISCIPLINE AREA — PHYSICS AND CHEMISTRY LABORATORY IN SPACE

#### SORTIE DESCRIPTIVE TITLE

- Wall-less Chemistry Facility
- Superfluid Helium and Drop/Particle Positioning Facility
- Fluid Physics and Heat Transfer Facility
- Neutral Beam Facility

#### REASONS SORTIE MODE PREFERRED

In these missions, advantage will be taken of the shuttle as a transportation system to carry experiments into space where investigators can exploit such unique environmental features as zero "g", vacuum, and solar radiation. These are laboratory-type physics and chemistry experiments which require many intricate operations. These experiments typically yield little data and require man to conduct the experiment. As discussed below, it is not clear that the experimenter himself need be present in the facility.

#### REQUIREMENTS ON SHUTTLE

Requirements this type mission places on the shuttle if the potential contributions are to be realized:

- Length of Flights — 7 to 30 days is satisfactory.
- Orbit — As high as 350 miles.
- Data Requirements — Will be generated during current experiment studies.
- Role and Number of Personnel in Orbit — See above.

- Stabilization and Pointing — 1 appears to be satisfactory.
- Power and Thermal — To be determined.
- Weight and Volume — Weight and volume now envisioned appear to be adequate.
- EVA Requirements — None contemplated.
- Correlative Measurements — Will be identified in current experiment studies.
- General Support Equipment — See above.
- Documentation Requirements — See above.
- Special Operating Constraints — Drop dynamics apparatus should be located near C.G.
- Contamination Requirements — Minimize contamination in the vicinity of the shuttle.
- Other — Many physics and chemistry experiments can be put into small groups that may not require a full Sortie lab. These groups could be included as part of other Sortie labs.

## RECOMMENDED POLICIES AND PROCEDURES

1. The shuttle should furnish transportation of experiments and the experimenter, his surrogate, or the ground-based facilities required to operate his experiment remotely. NASA and not the experimenter should pay for this. The experimenter must provide the experiment and should be responsible for integrating his experiment into the Sortie lab.
2. Experiments should be chosen as they now are chosen in other national facilities such as observatories, radio telescopes, nuclear reactors, and accelerators. Such facilities have user groups who determine the experiments to be performed.
3. The R&QA, training, and documentation requirements must be kept to a bare minimum if one wishes to have a workable and cost-effective Sortie lab. CV 990 should be a model for handling documentation.

4. The results of low-cost payload studies currently underway should be included in guidelines for future payload designs. These results should not be of such a nature as to cause substantial additional R&QA and documentation requirements. Use of modular components which experimenters can assemble into experiment apparatus will minimize cost, documentation, interface requirements, and R&QA. Furthermore, use of modular equipment will allow Sortie lab technicians to be trained to repair standard equipment. Modularity can also help provide standard equipment to allow for automation of experiments. Modularity will also make it less costly to provide remote control of experiments by ground-based experiments. A more extended discussion of remote operation by experimenters is given below.

#### ESTIMATED MAGNITUDE OF SORTIE MISSION USER COMMUNITY

The authors expect the physics and chemistry laboratory to provide easy access to space for the entire technical community of physicists and chemists, both national and international. In the U.S. alone, this group numbers well over 100,000. As a guess, 1 in 10 will make use of the shuttle-borne physics and chemistry laboratory by either conducting experiments in the laboratory or by analyzing data gathered in the laboratory by others.

#### RECOMMENDED APPROACHES FOR INTERFACING WITH THE USER COMMUNITY

In the current study the authors are already interfacing with the NASA user community and, to a limited degree, with the academic community. In addition, the National Science Foundation is currently participating in this study and is assisting in evaluating the scientific merit of experiment proposals. One may expect more extensive involvement by the National Science Foundation as well as by the National Academy of Science.

#### RECOMMENDATIONS ON FUTURE ACTIONS

1. A meaningful experiment program in the 1980's and the late 1970's demands an aggressive development of candidate experiment concepts and an intense experiment definition effort that must begin now.
2. Remote Operation of Sortie Experiments By Ground-Based Experimenters.

The required training of an experimenter, if he wishes to fly on the shuttle will deter many potential experimenters who are, after all, busy men. On the other hand, experimenters may not be willing to entrust operation of their experiment to others. Moreover, even if an experimenter does entrust operation of his experiment to others, it will be difficult and time consuming to train the person who will fly. For these reasons, remote operation of Sortie lab experiments by experimenters stationed on the ground should be given consideration. Such a provision would make the use of shuttle much more attractive to experimenters, thereby increasing the market for shuttle use.



The following are the contents of each volume of this series:

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VOLUME 3 — HIGH ENERGY ASTROPHYSICS

VOLUME 4 — LIFE SCIENCES

VOLUME 5 — SOLAR PHYSICS

VOLUME 6 — COMMUNICATIONS AND NAVIGATION

VOLUME 7 — EARTH OBSERVATIONS

VOLUME 8 — EARTH AND OCEAN PHYSICS

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